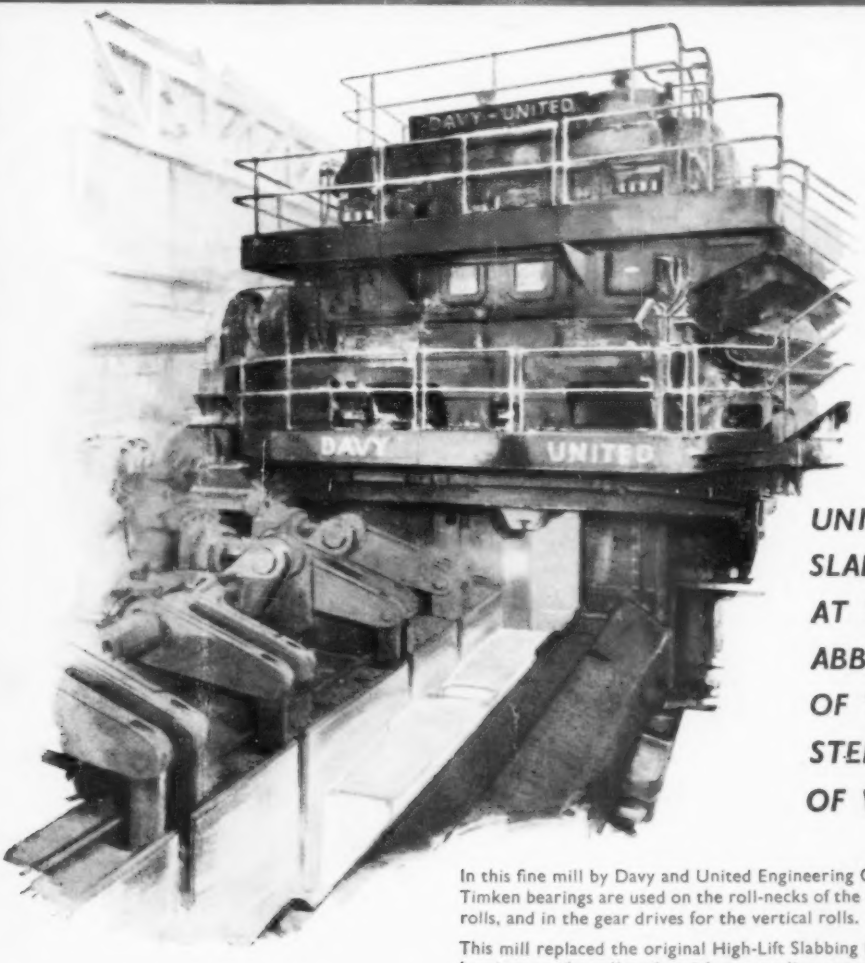
Sheet Metal Industries

The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

VOL. 38 : No. 406 FEBRUARY 1961 PRICE 2/6



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In this fine mill by Davy and United Engineering Company Limited, England, Timken bearings are used on the roll-necks of the vertical and horizontal rolls, and in the gear drives for the vertical rolls.

This mill replaced the original High-Lift Slabbing Mill which used Timken bearings on the roll-necks with outstanding success.

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* THIS MILL RECENTLY ROLLED 10,000 TONS OF INGOTS IN ONE DAY: 65,341 TONS IN ONE WEEK.

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REGISTERED TRADE-MARK
tapered roller bearings

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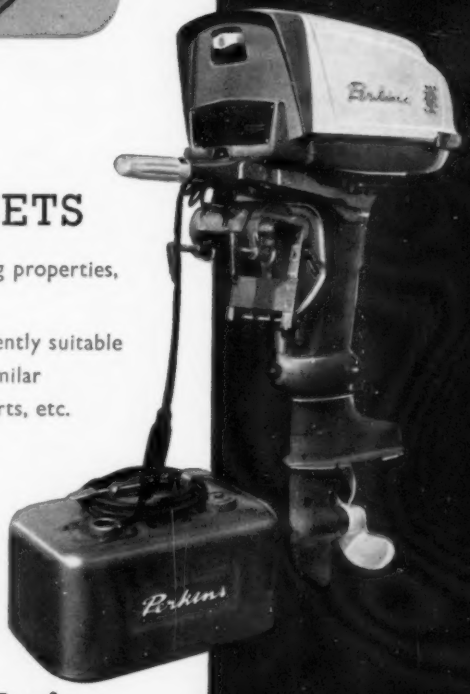
RTB terne-coated sheets have excellent working properties, lending themselves to all fabricating processes.

Their resistance to corrosion makes them eminently suitable for petrol tanks, fire-extinguishers and other similar containers, and for ventilation ducting, radio parts, etc.

Further, they form an excellent basis for most industrial paints.

The illustrations show the neat fuel tank of the Perkins outboard motor. The clean lines obtained by the deep-pressing are made possible by the quality of the RTB steel which is the basis of the terne-coated sheets.



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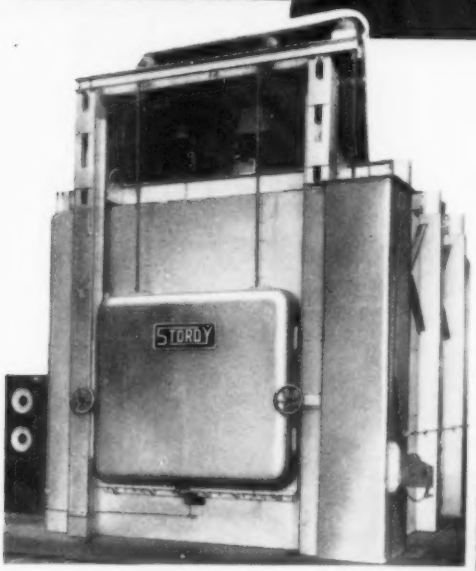
HEAT TREATMENT FURNACES



The range of Stordy heat treatment furnaces include batch, pit and continuous types, heated by oil, gas or electricity, with indirect firing when required. The Stordy system of forced air circulation is unique in its efficiency and in providing rapid heating up rates and uniform heating conditions throughout the chamber with maximum fuel economy. Stordy heat treatment plant includes all the necessary materials handling equipment—robust charging and discharging machines, conveyors, transfer tables, loading and unloading racks.

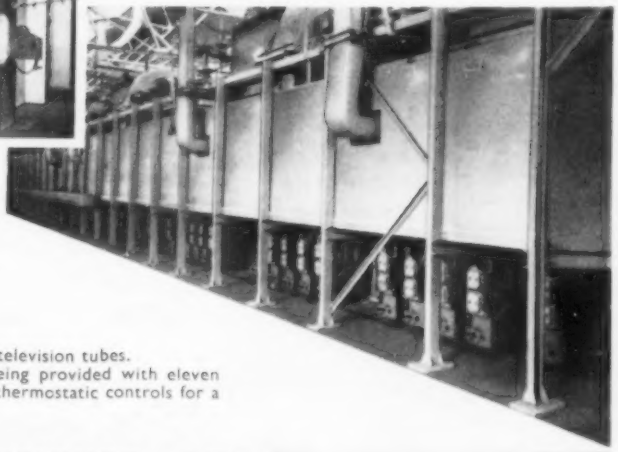


Illustration above:
Electrically heated, air circulated batch-type furnace for aluminium.
Working temperature 600° C., the furnace being complete with electric heater batteries and circulating fans, designed for ease of removal.

Illustration right:
High temperature heat treatment oven for television tubes.
The oven has a heated length of 206 ft. being provided with eleven combustion chambers, circulating fans and thermostatic controls for a maximum temperature of 450° C.

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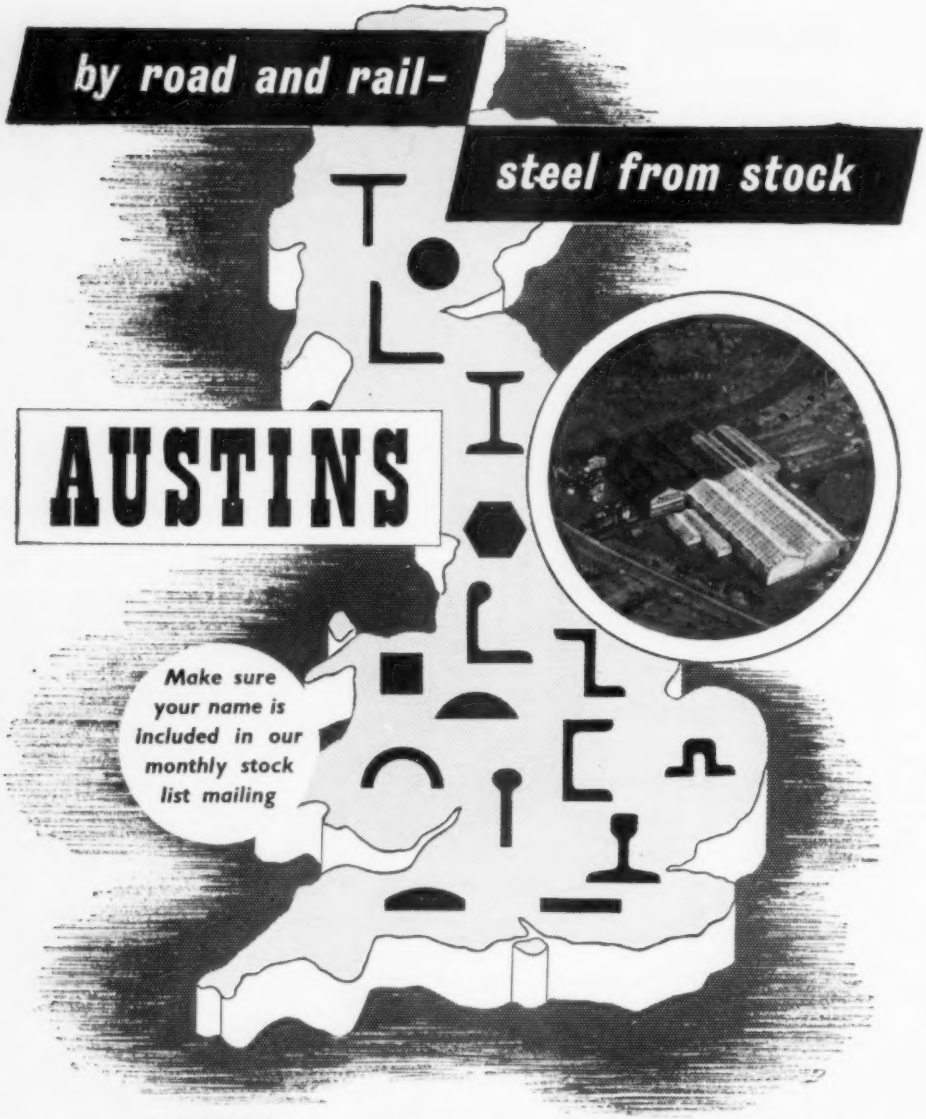

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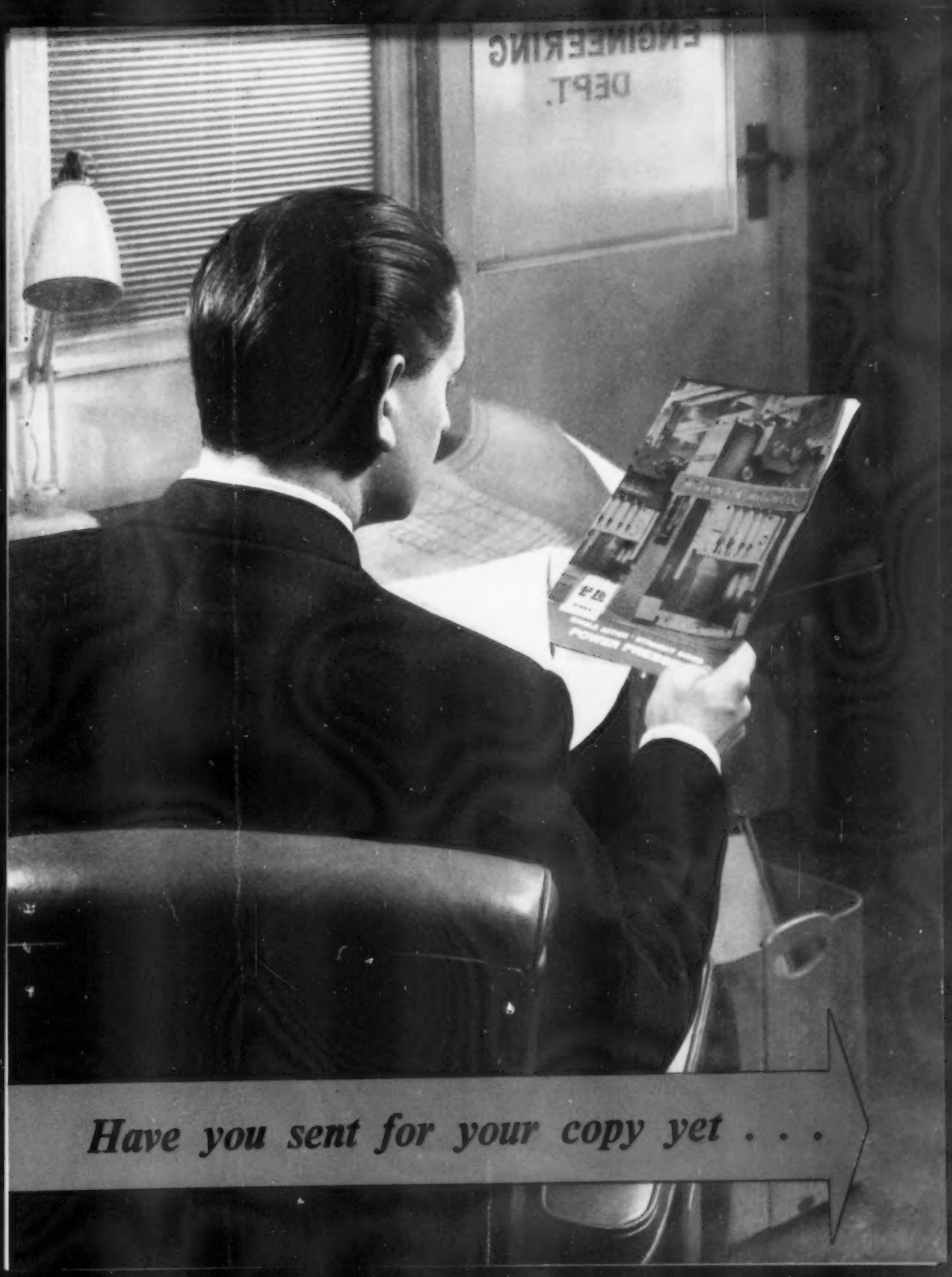

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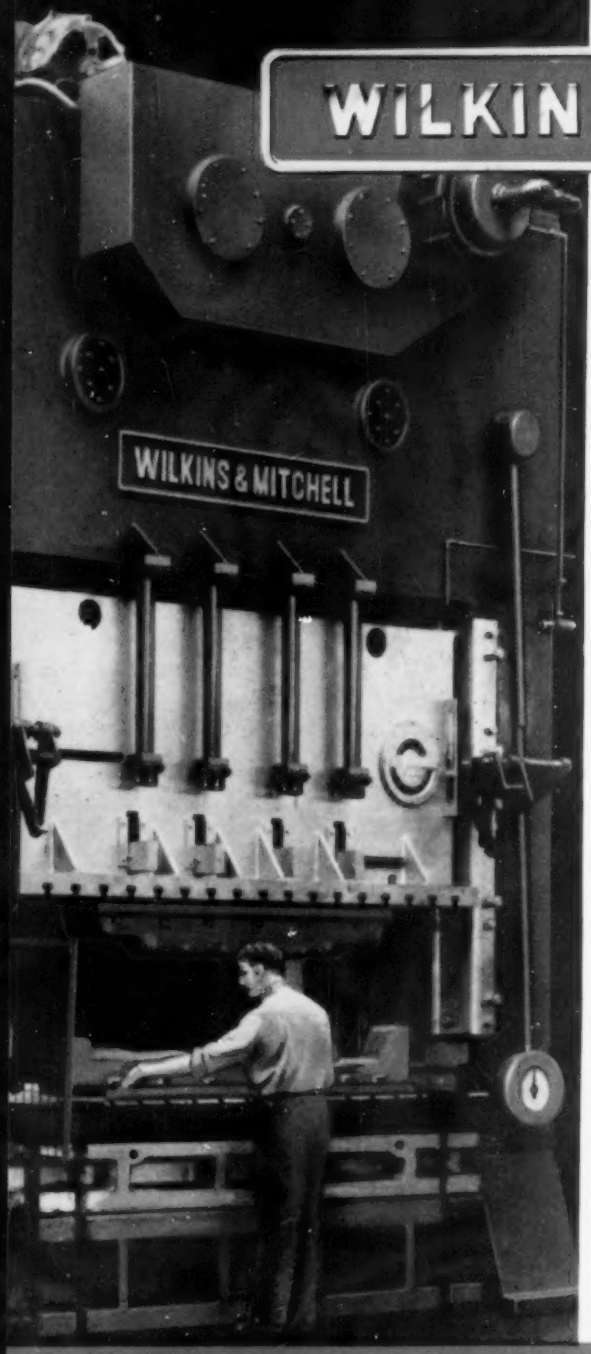

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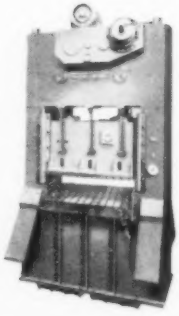

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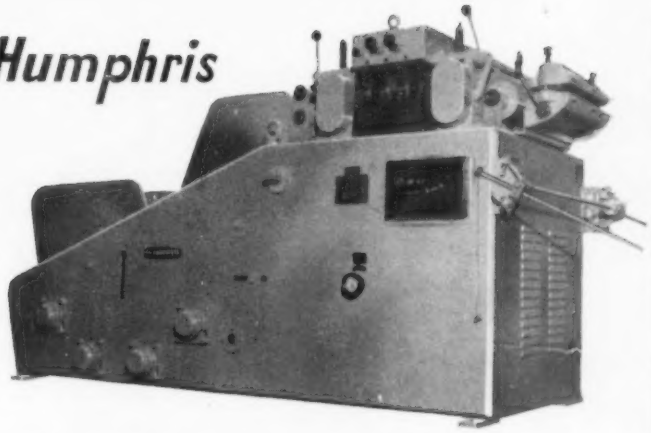

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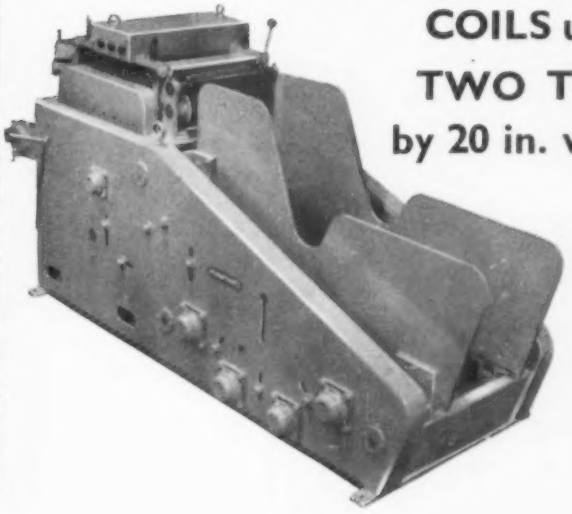

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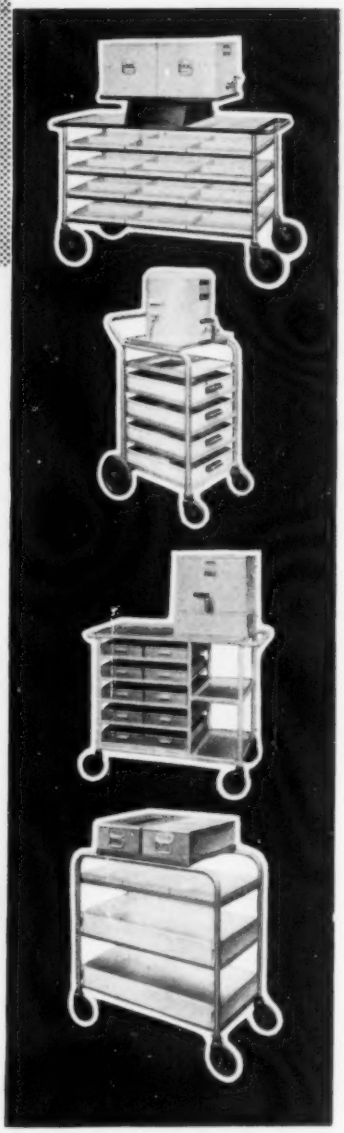

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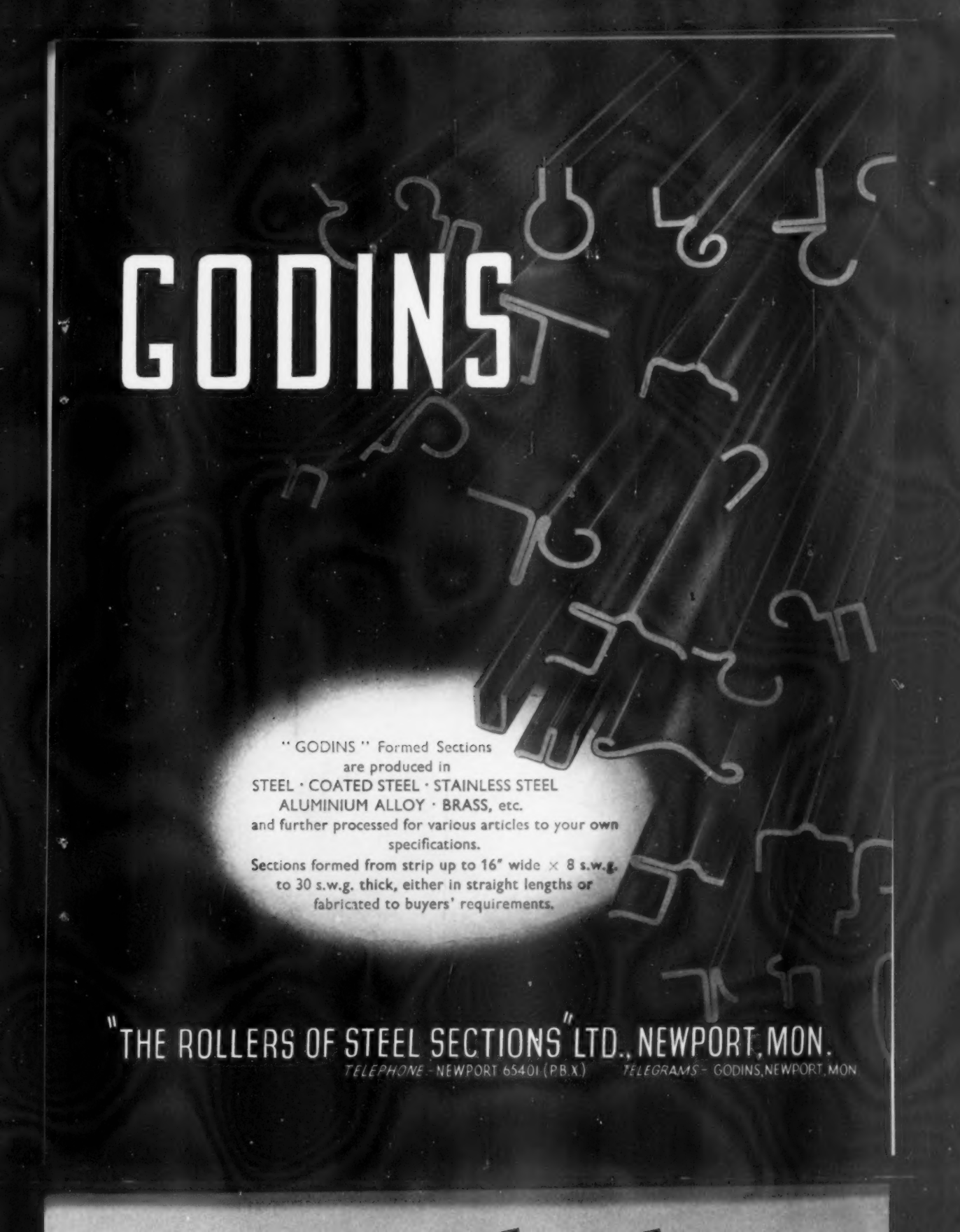

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CORBY

known by many as —

CLUES ACROSS

3 'Stand-in' has fatal accident (6, 6)
10 This number is not, however, necessarily between 12 and 20 (7)
11 Where I get into 8 (4)
13 Light and fantastic for a tripper, according to Milton (3)
16 Topping distinction for a player (3)
17 A small administrative section needs an expert (5)
19 One way of joining our product, only apparently by the sound of it (7)
20 Lawsuit with (probably) four parties involved (6, 6)
21 None can produce such light (4)
22 Divine extremities of 3 across (2)
23 Blazes! get down (6)
27 You'll find its double in 12 (2)
28 One can do it in the Wheatsheaf (3)
29 Not for Greensleeves but for Episcopal ones (4)
30 Father has got out of PAYE (2)

CLUES DOWN

1 For those with high blood pressure? (7)
2 Reserved for later game (6)
3 Metal with this quality behaves well under operation 1 (7)
4 Just the fellow to roam round (4)
5 Heaven is their land (4)
6 The doughboy should be able to (5)
7 Baltic dweller has sound permit (4)
8 Up and down previously (3)
9 At the top of the chapter (4)
12 Does the goddess lead a double existence? (4)
13 Not paper money (3)
14 A singular person, (3) - - -
15 and how the Roman identified him (3)
18 The copper is a card (2)
24 "This royal throne of kings, this sceptr'd - - - - " *(Shakespeare)* (4)
25 Cut like Mr. Gaitskell? (3)
26 The South African kind is the very devil (3)

'Lancs & Corby'

ELDAIR PRESS BRAKES

ELDAIR *Mechanical* PRESS BRAKES

Bending Capacities between frames from 4 ft. x $\frac{3}{16}$ in. M.S. to 12 ft. x $\frac{1}{4}$ in. M.S.

- ★ All steel fabricated main frame.
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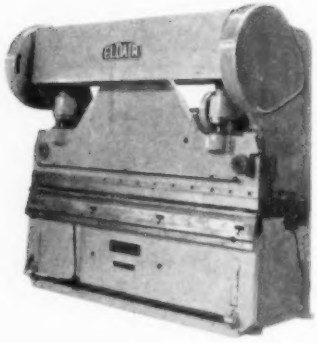
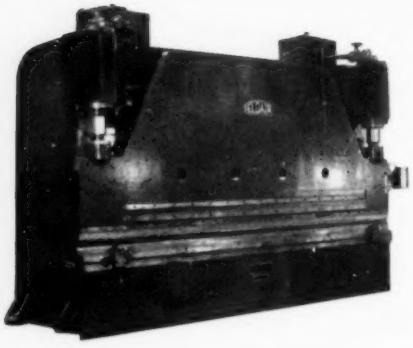


Hydraulic and Mechanical



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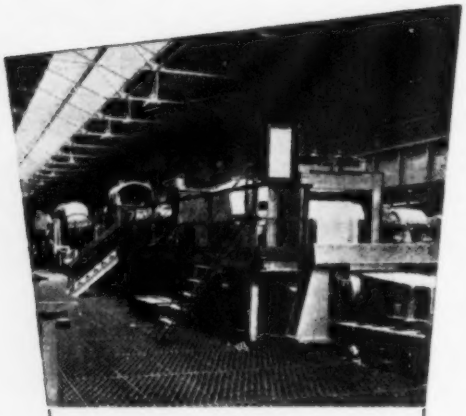

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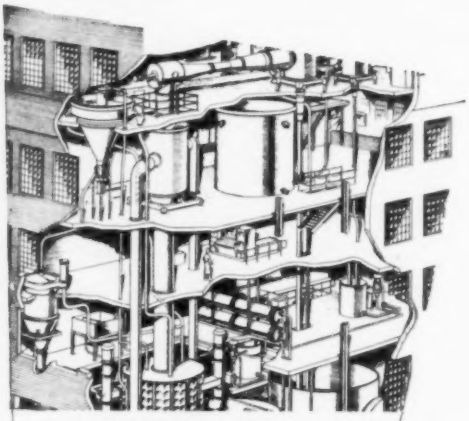

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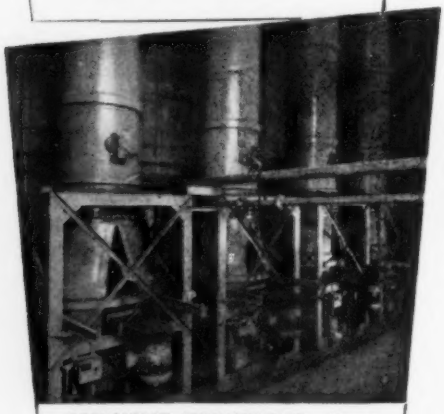

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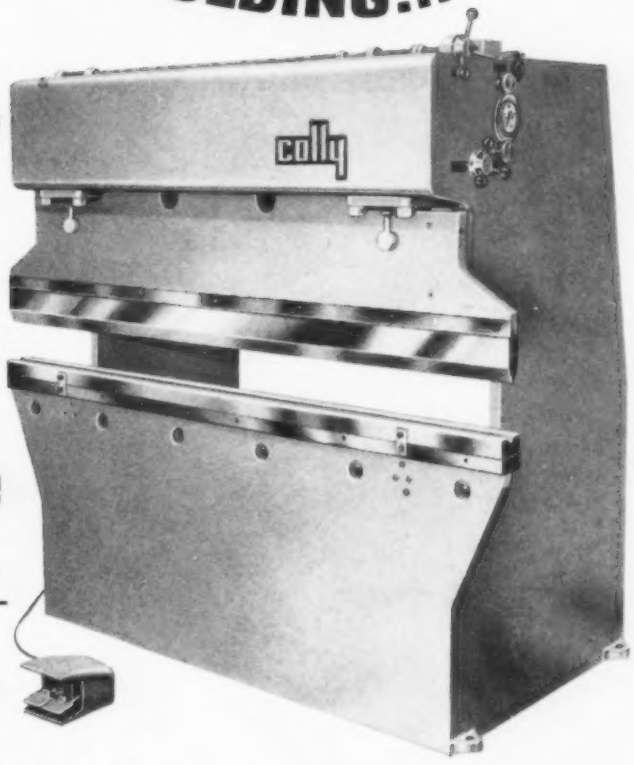

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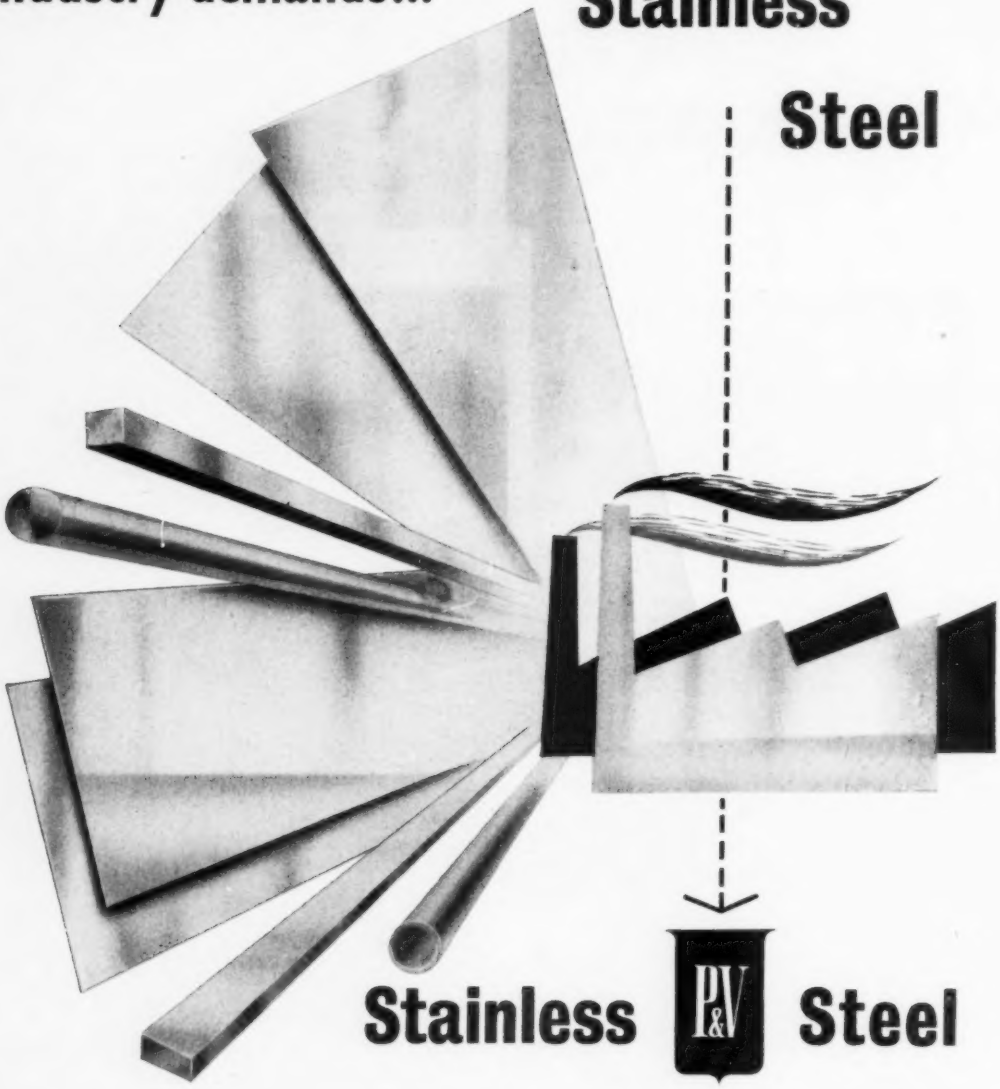

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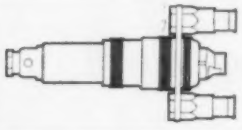
("The old goat!" muttered a faithful employee).



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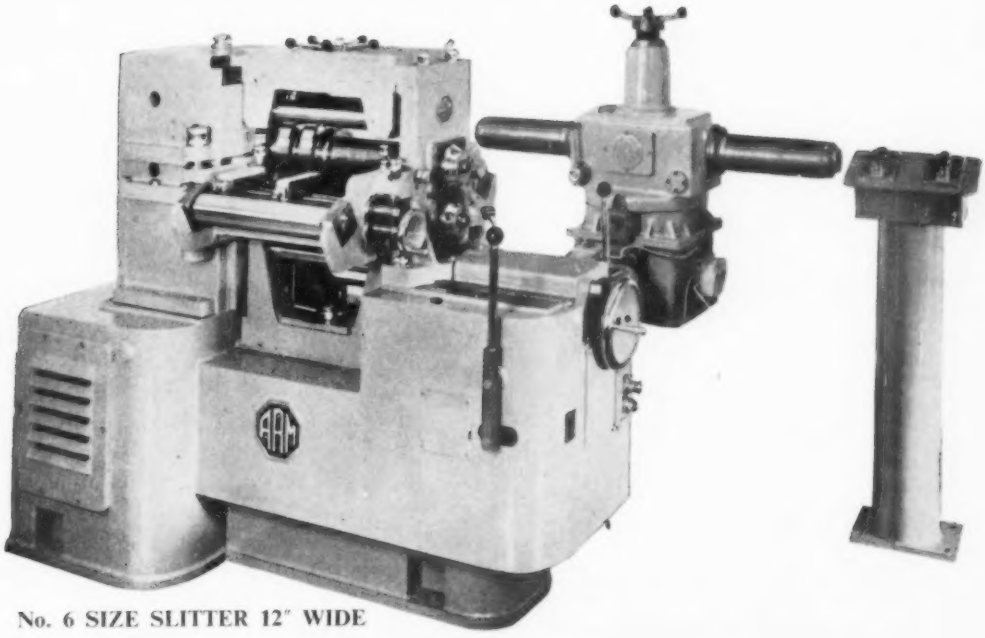

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Getting entangled with a welter of competing firms all plugging separate pieces of product finishing equipment is a frustrating, staff-consuming trial of strength —a trial in which the overall view of a complete finishing system can easily be lost. That is why so many front-line manufacturers have long since pensioned off the old, piecemeal approach to product finishing and now delegate the whole responsibility to a single, specialist organisation—Lysaght-DeVilbiss.

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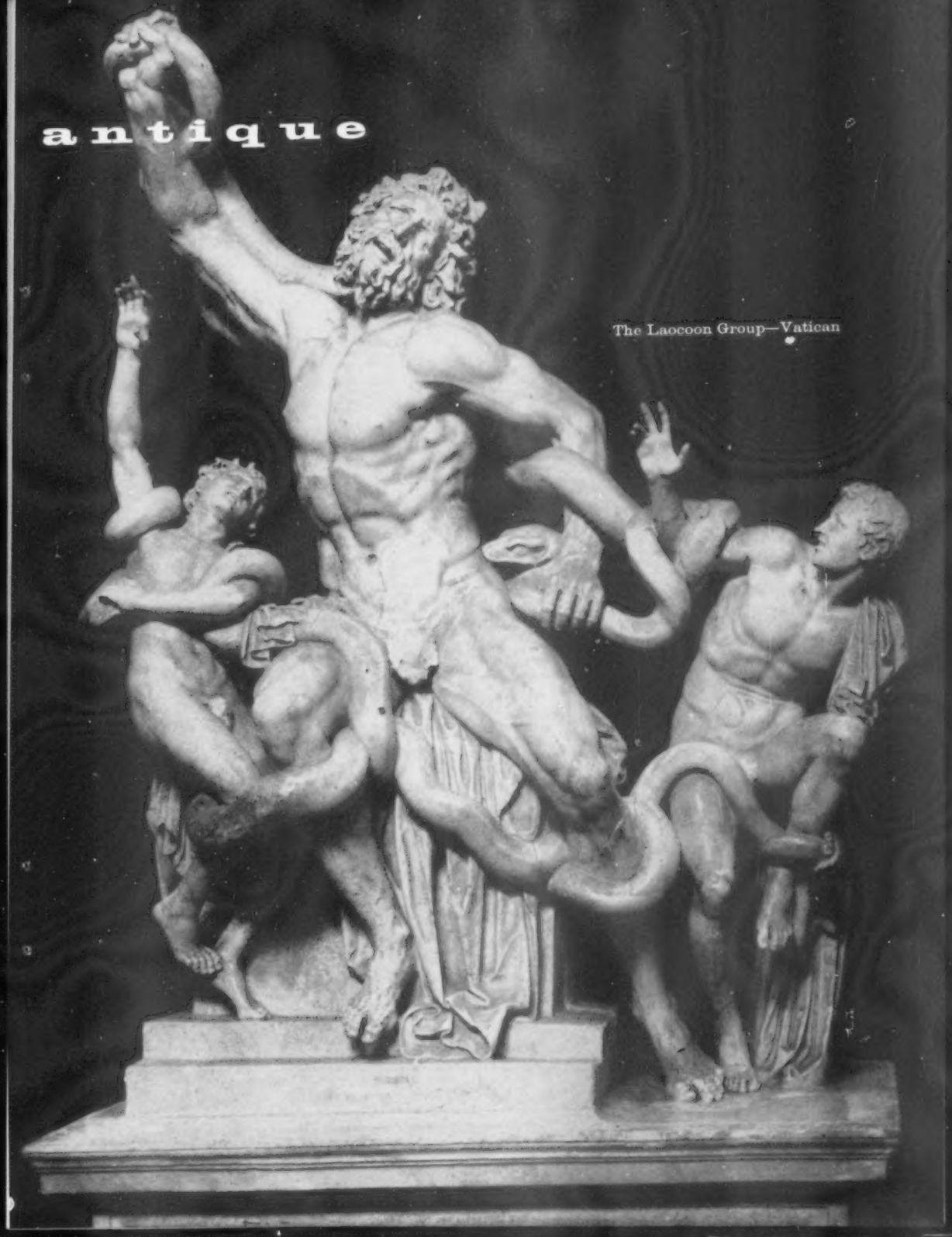

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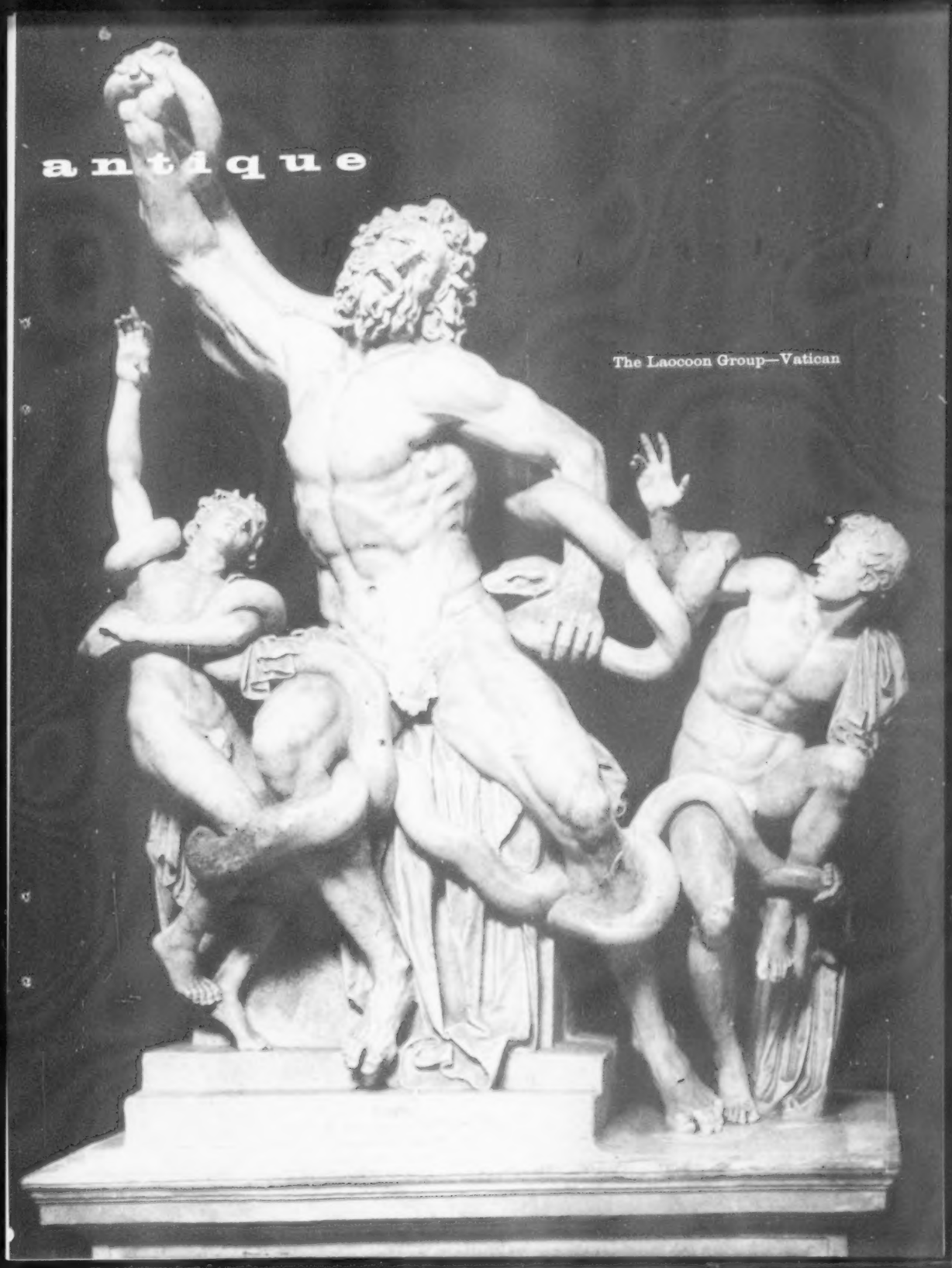

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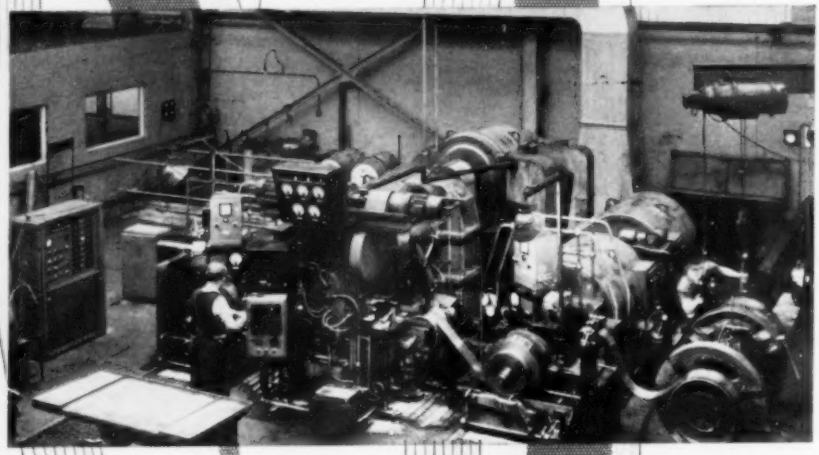

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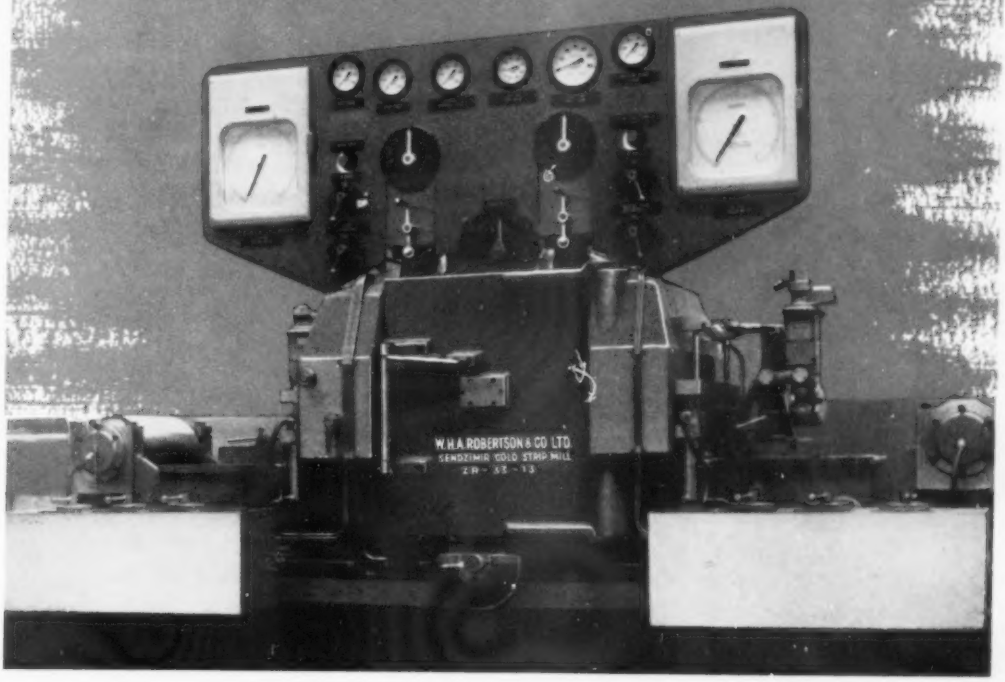

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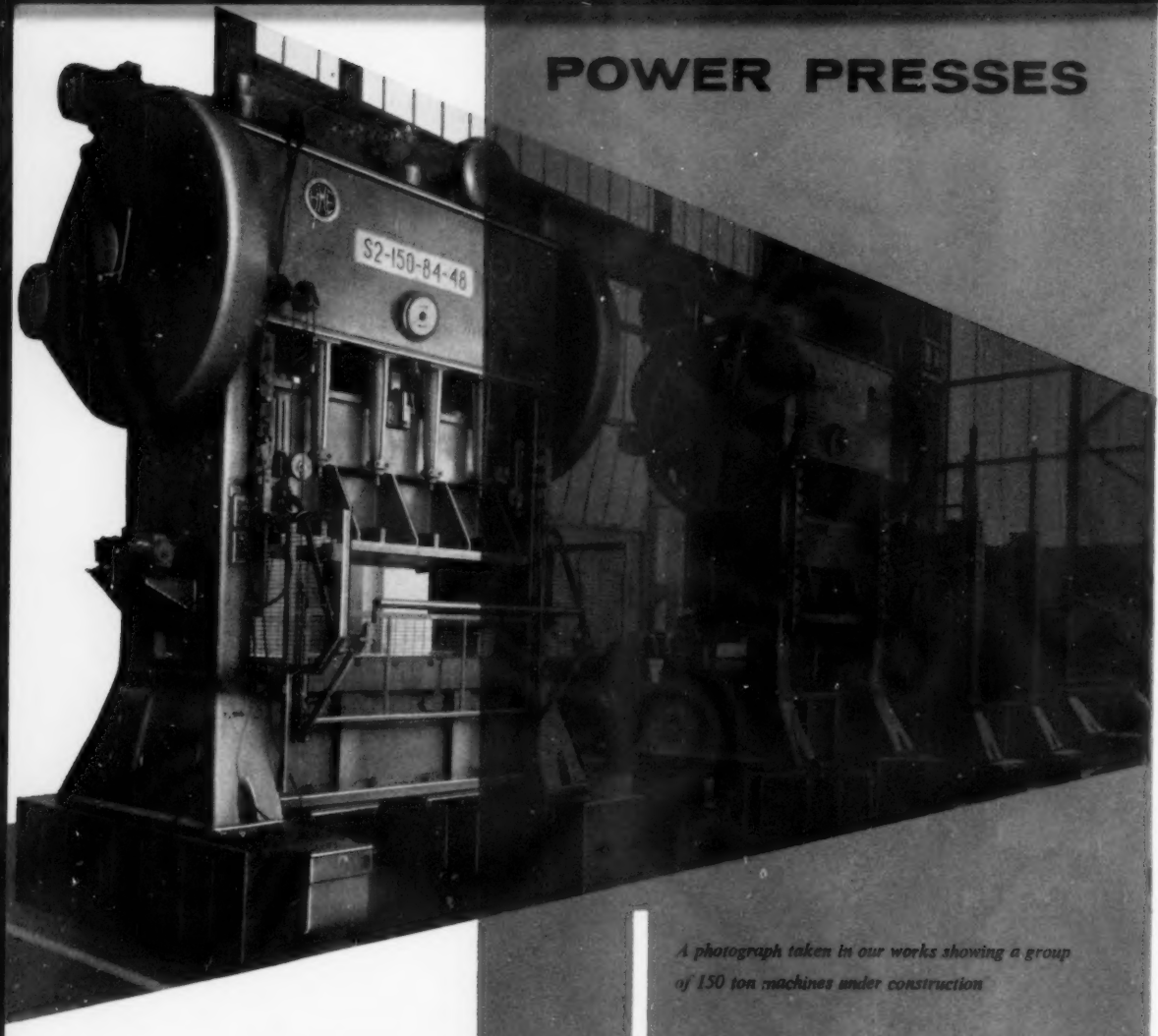

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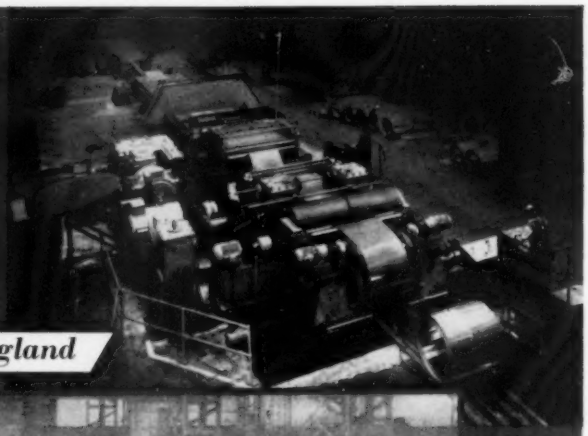

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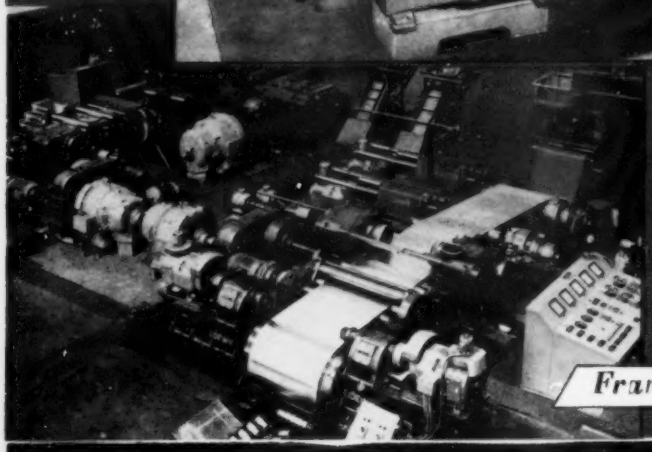

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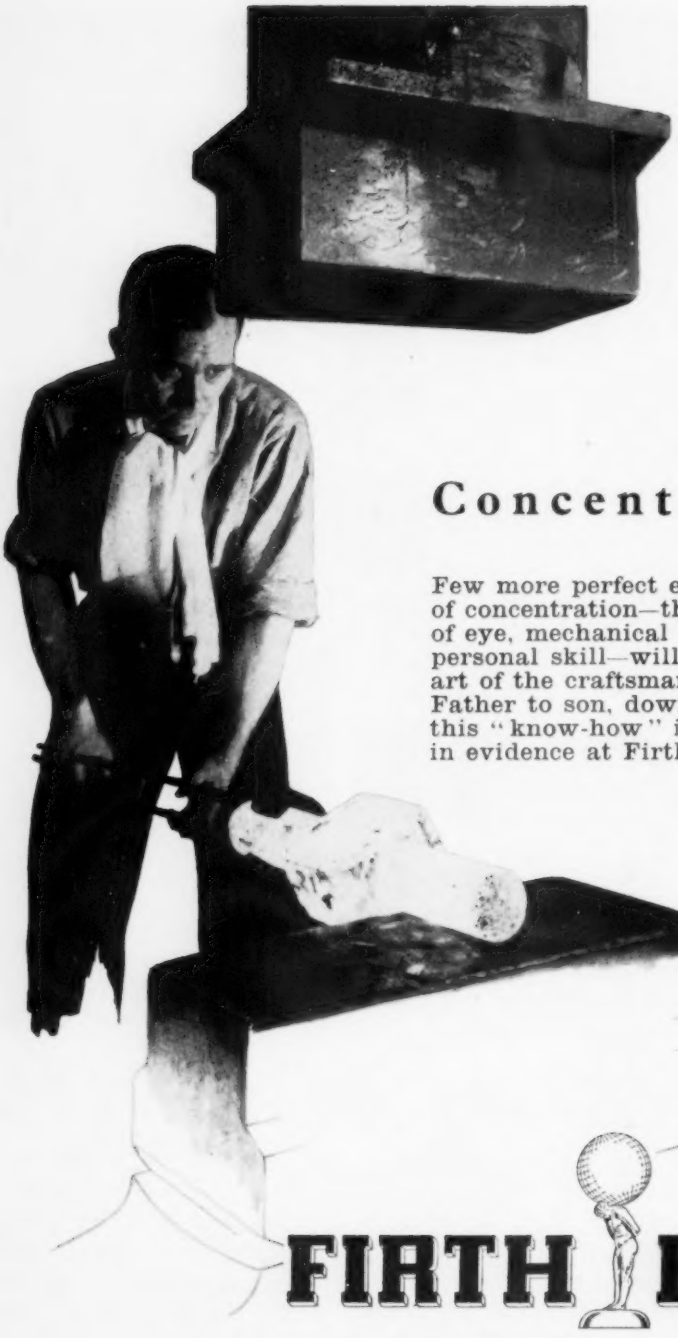

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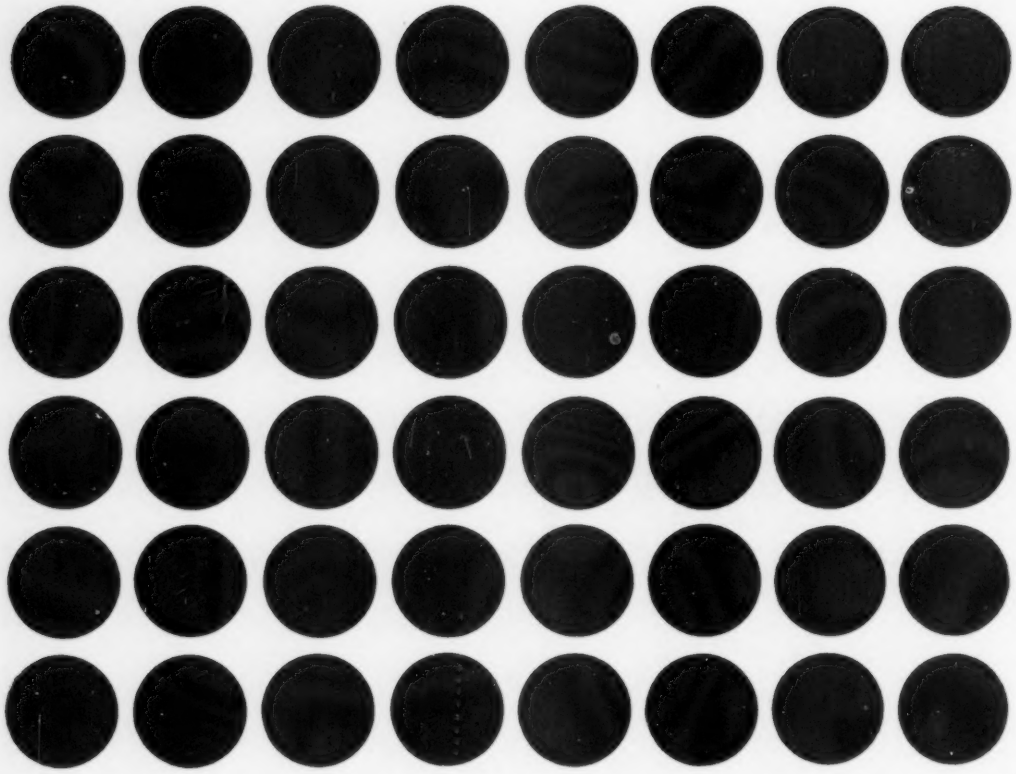

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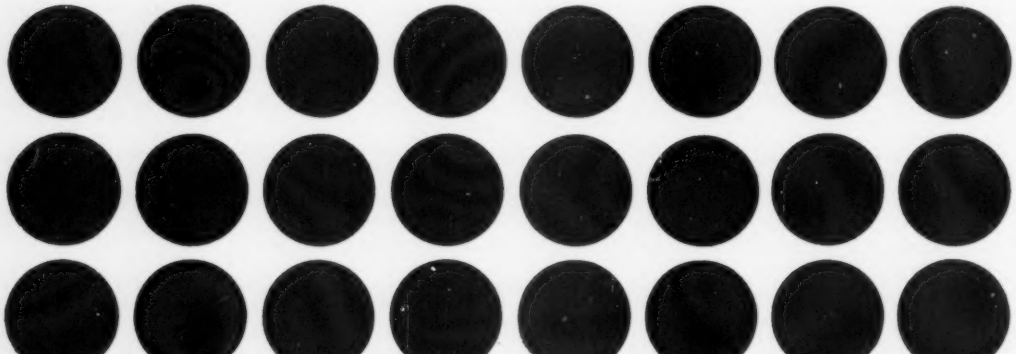

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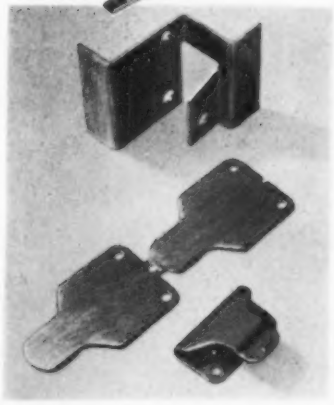

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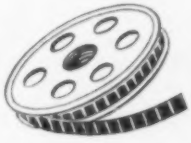

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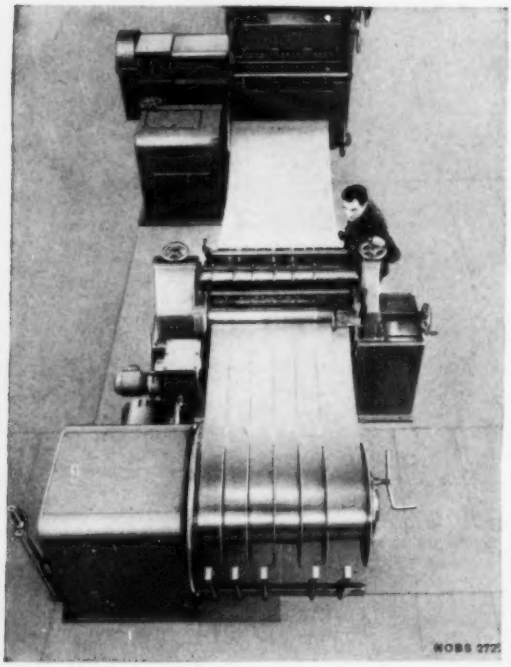

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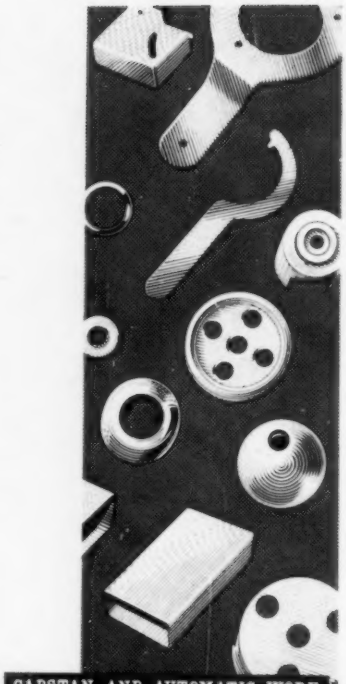

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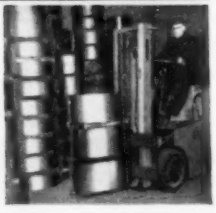

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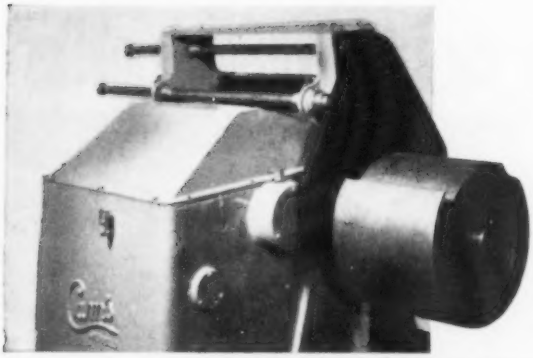

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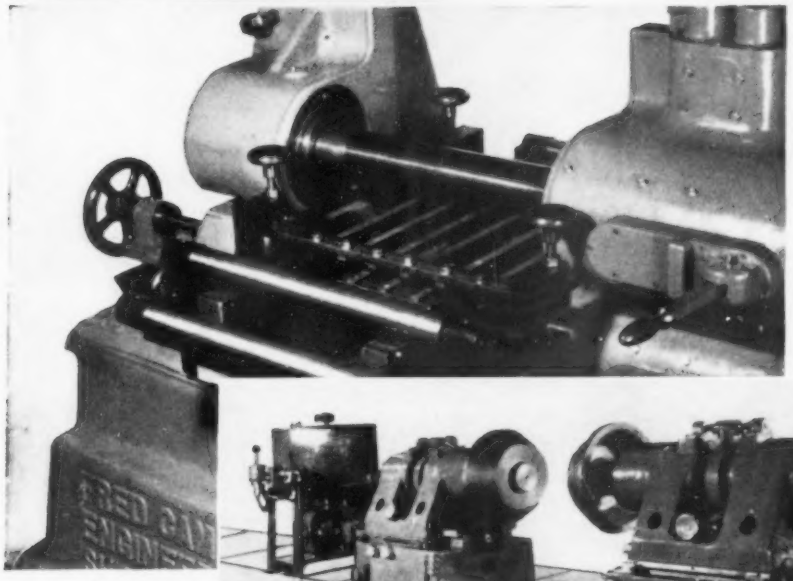

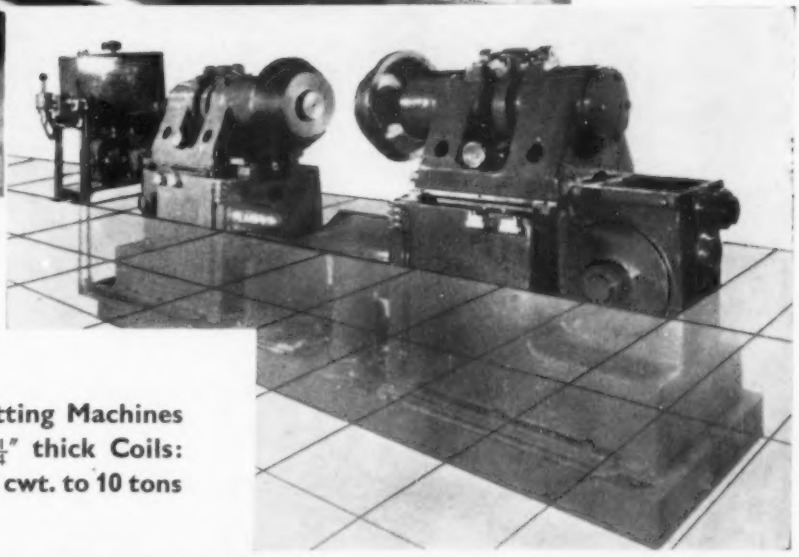

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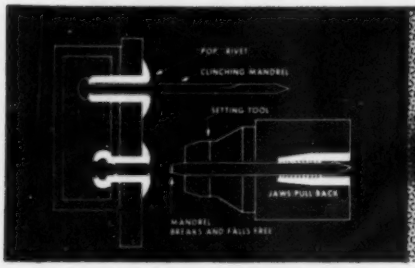

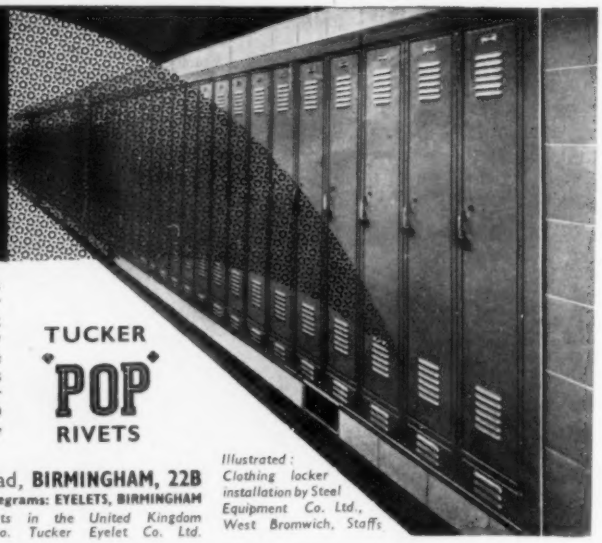

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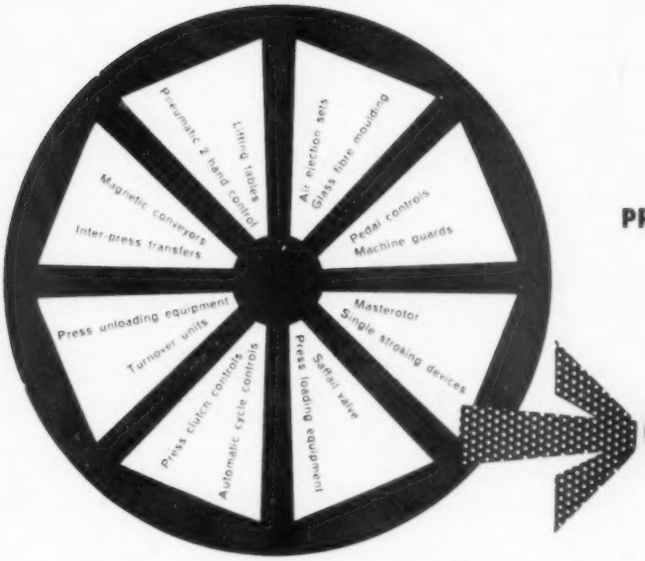

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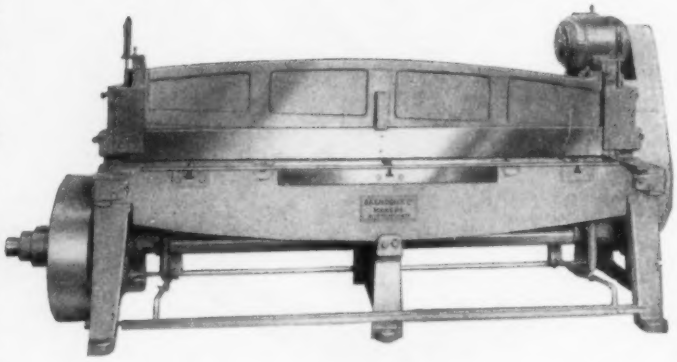

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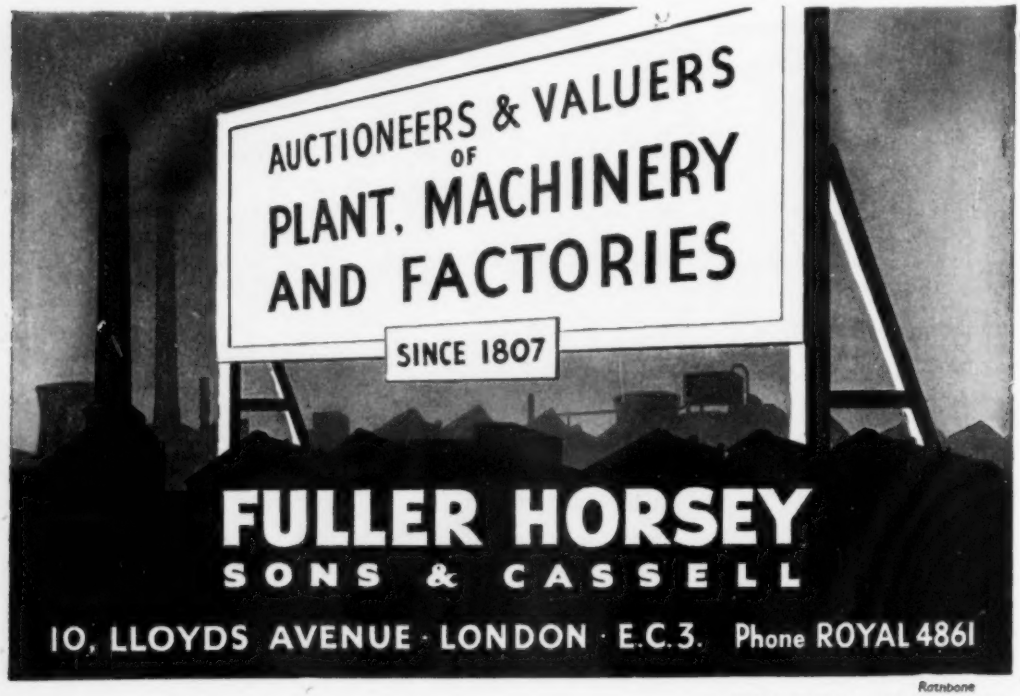

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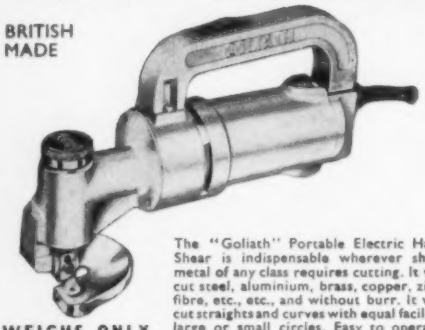

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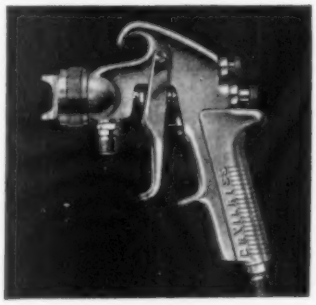

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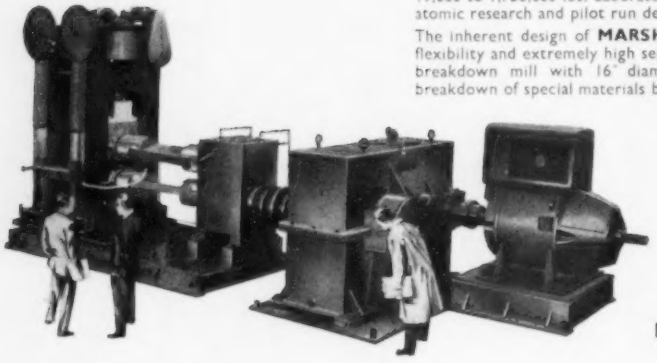

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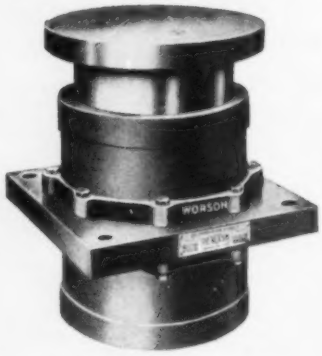

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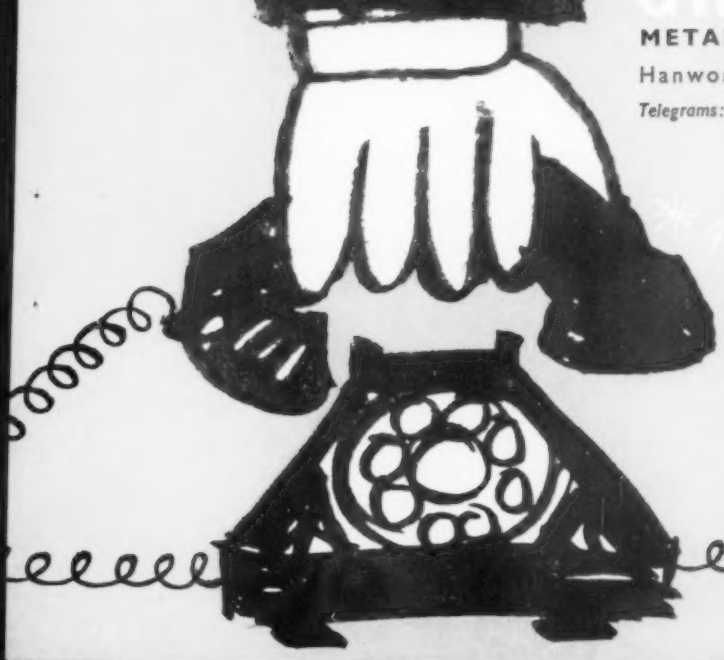

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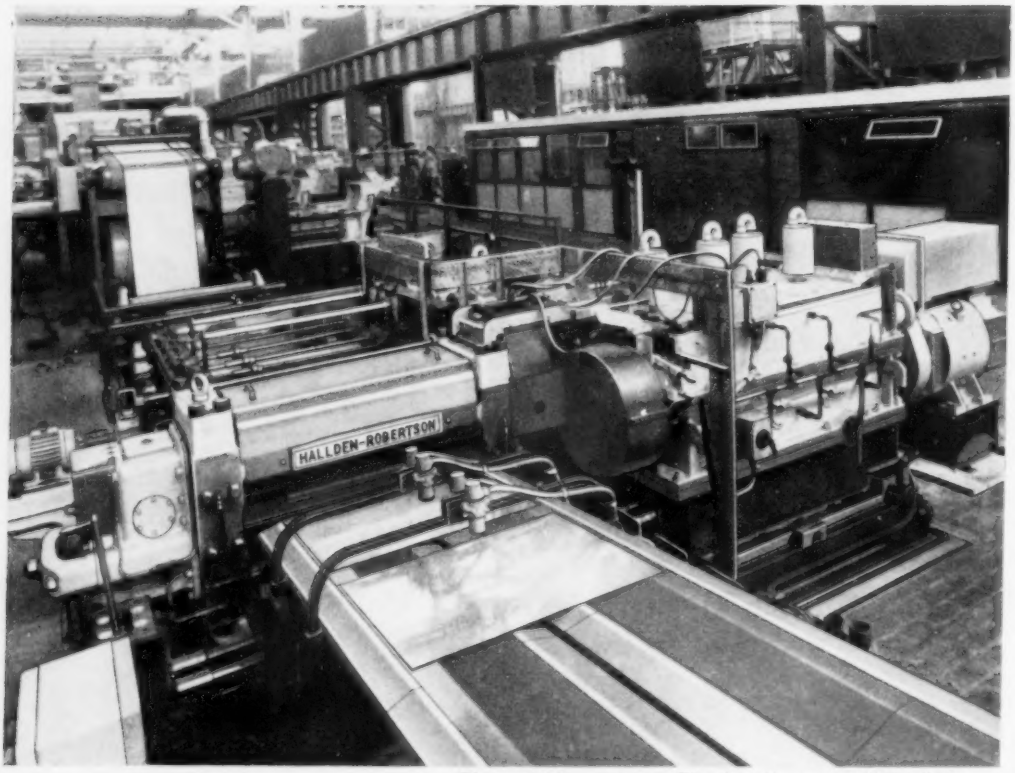

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The three Cut-up Lines fitted with this Hallden design machine are capable of dealing with all tin-plate gauges and sheet sizes up to a rate of 428 sheets per minute.

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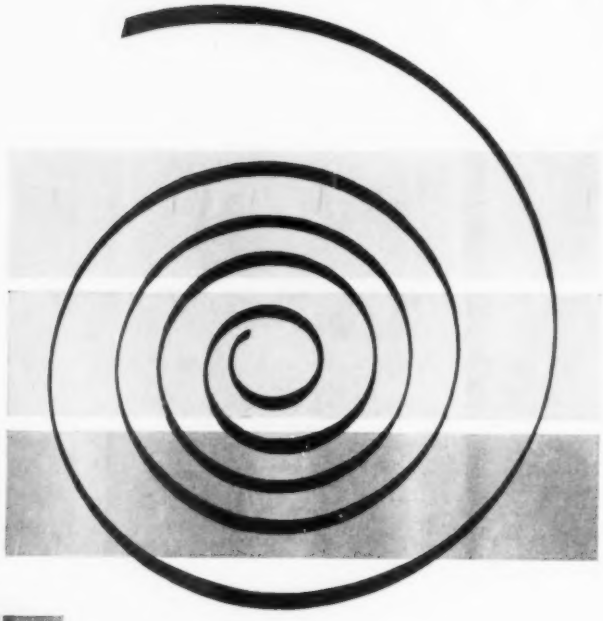

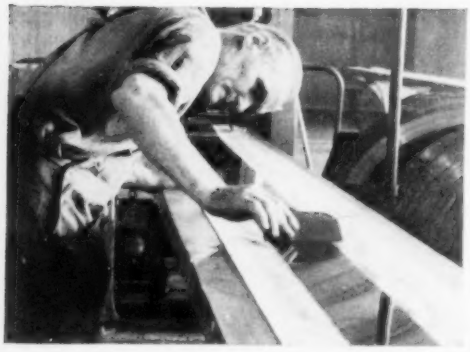

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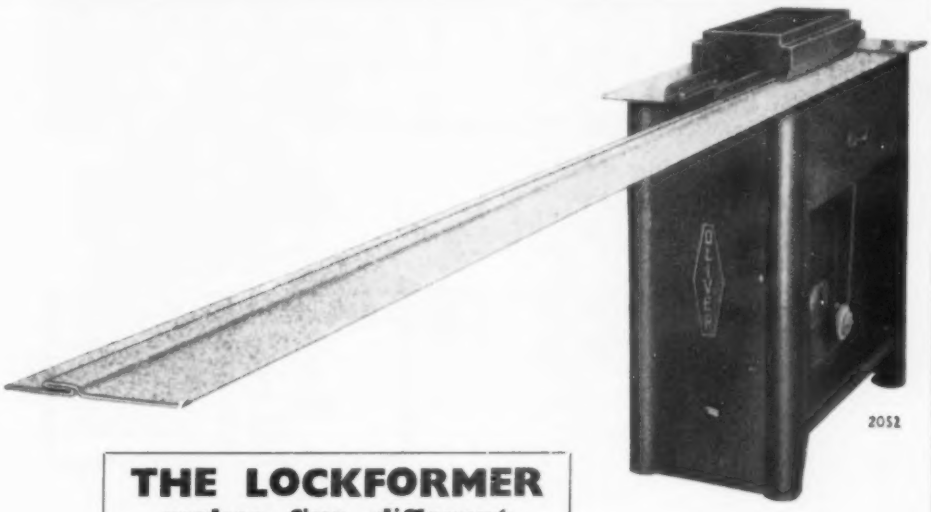

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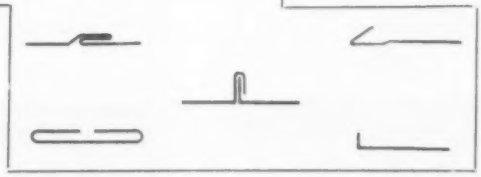

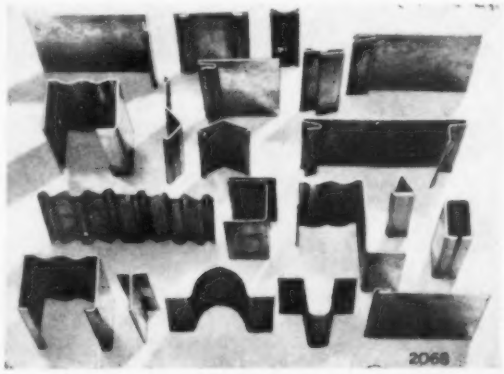

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Illustration on left shows some of the forms which can be produced by special Lockformers and rolls.

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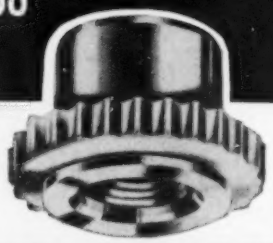
The ROSAN PRESS NUT



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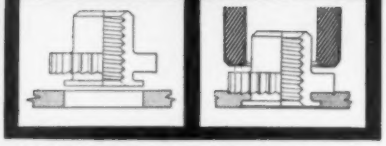

Apply impact force to exposed edge of serrated flange of Press-Nut. Note that impact flows sheet metal into space between flanges, locking the Press-Nut securely in place. Teeth of the serrated flange broach themselves into the parent metal preventing rotation.

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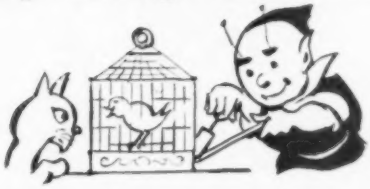
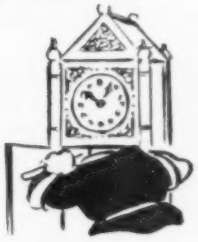


(c) keep things GOING...



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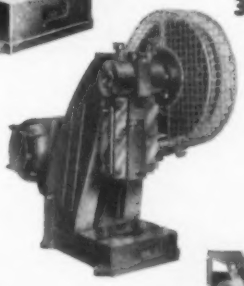
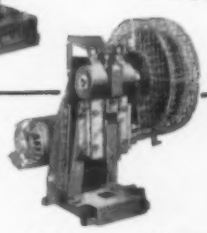


3 TON



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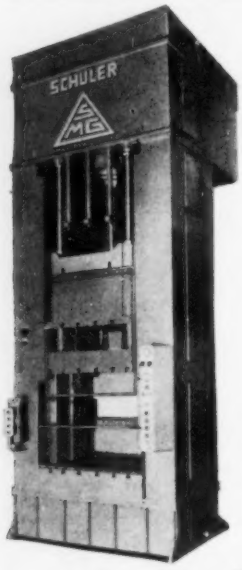

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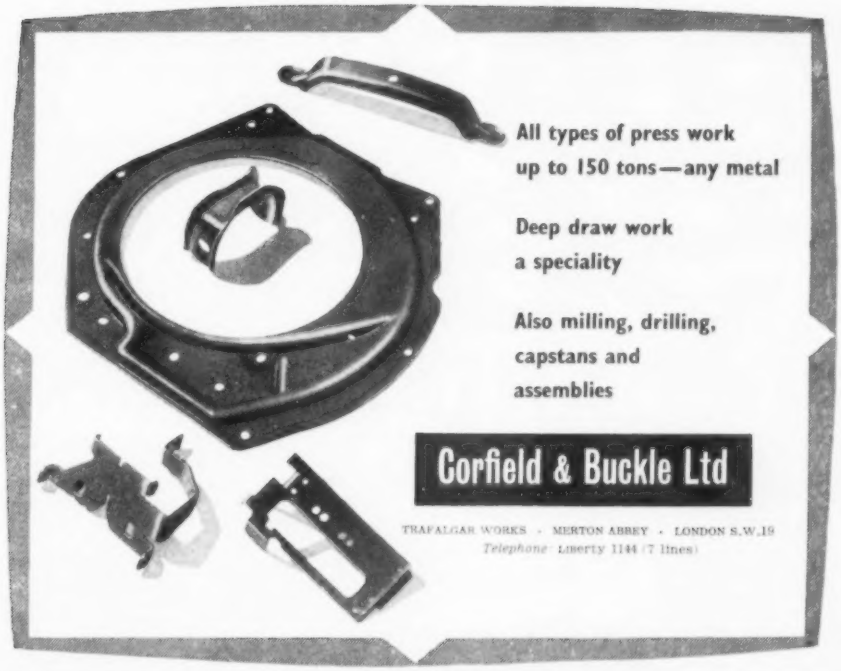
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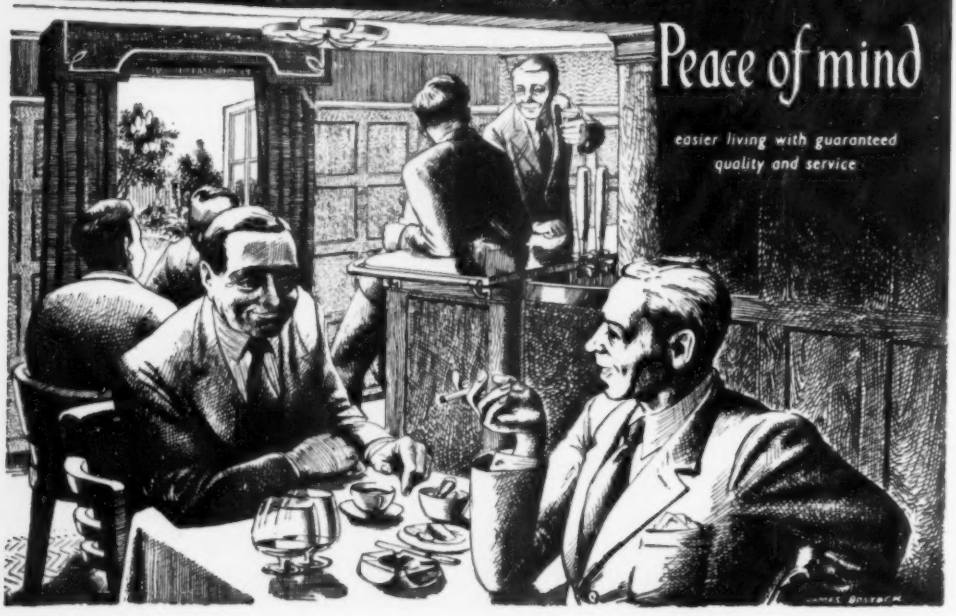

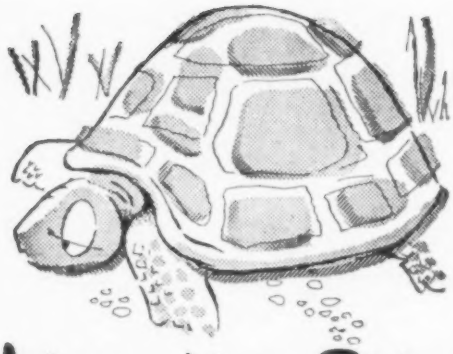

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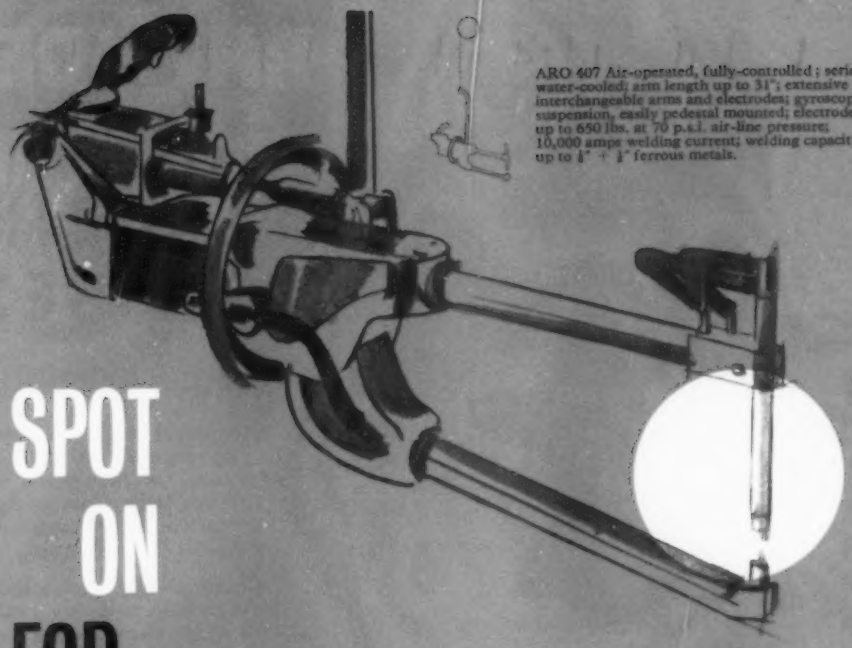

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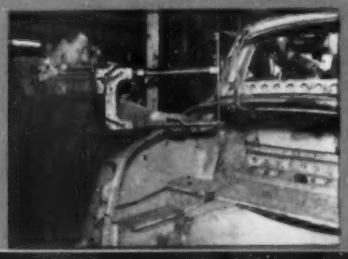
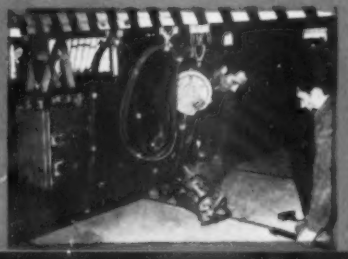
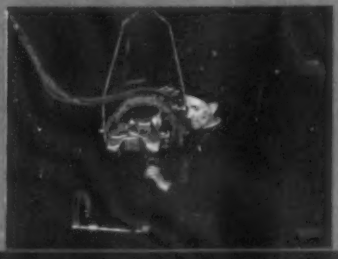
ARO 413 oildraulically operated gun welding a motor-car boot assembly.

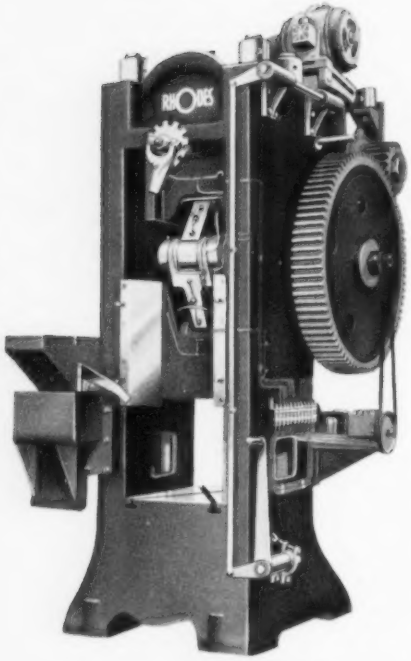


ARO 413 oildraulically operated gun welding wall panels in pre-fabricated houses.



ARO 510 "Plate-Master" gun spot welding structural steel assemblies.





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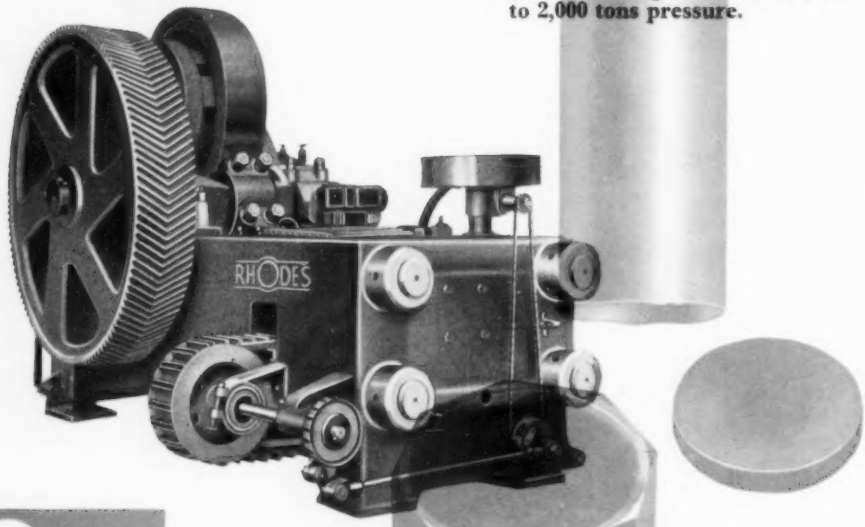

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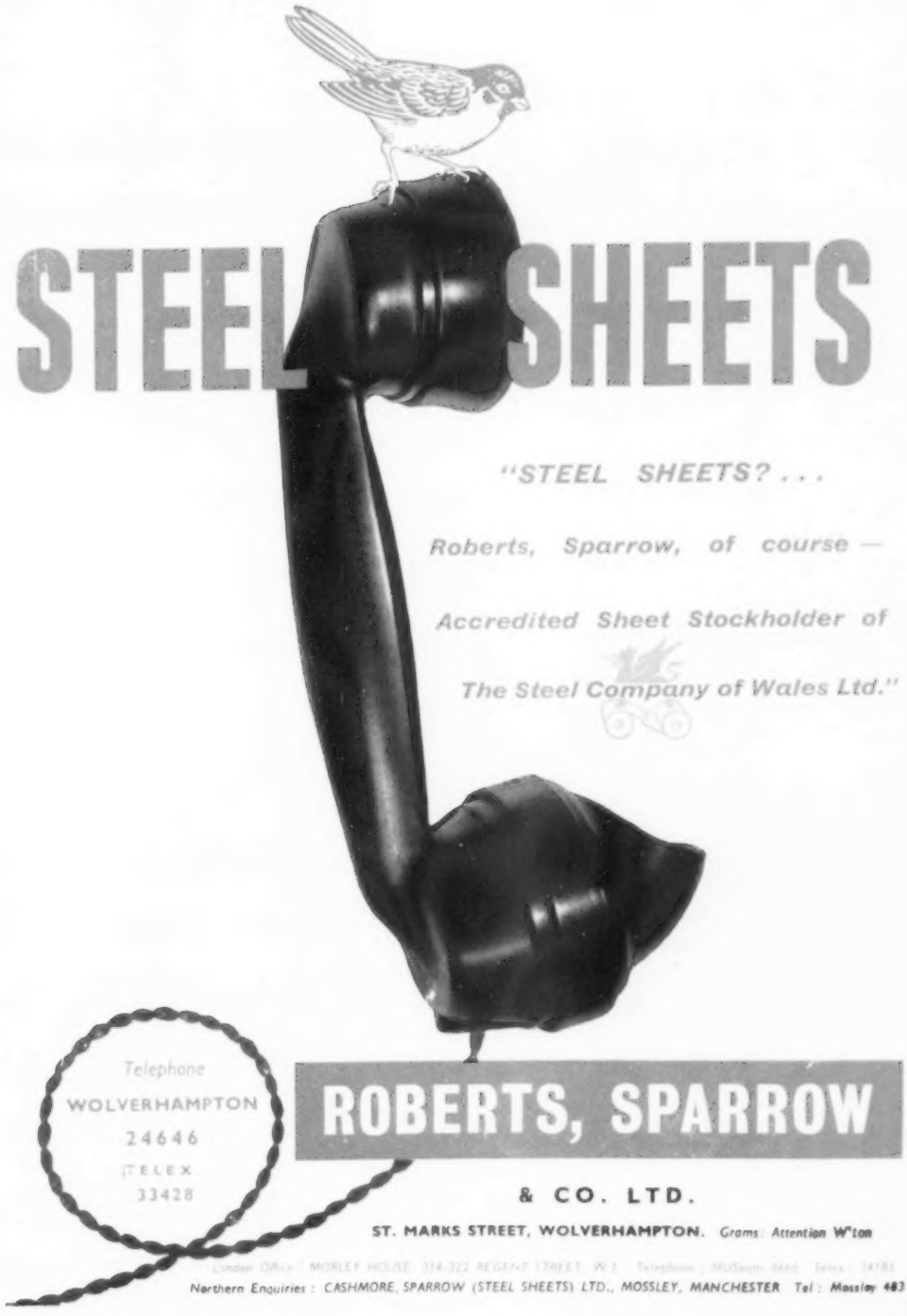
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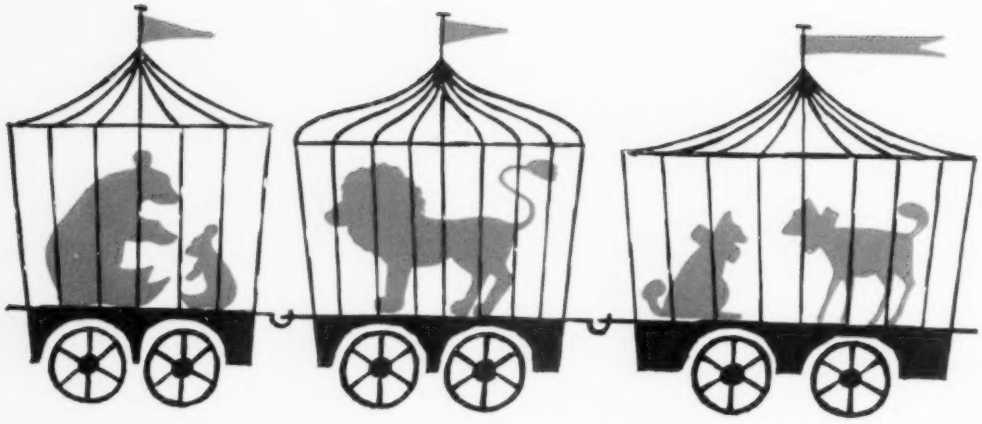

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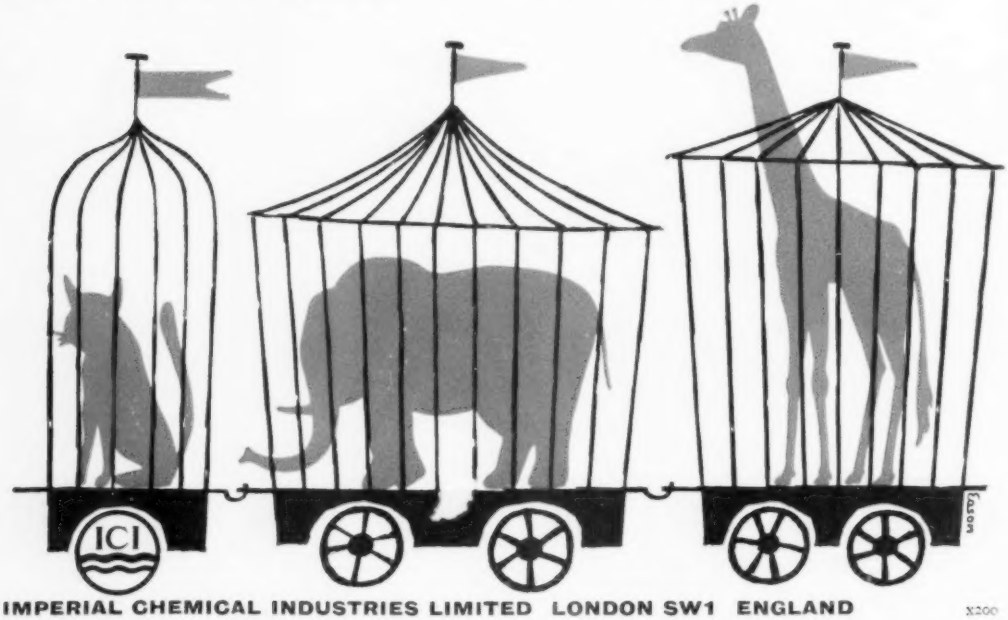

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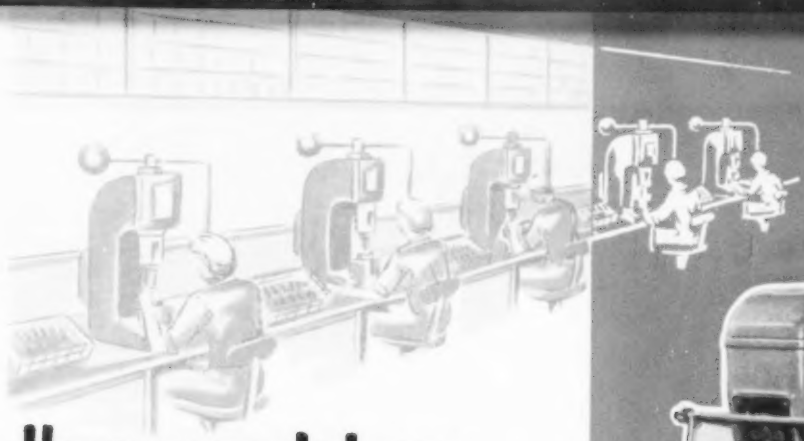
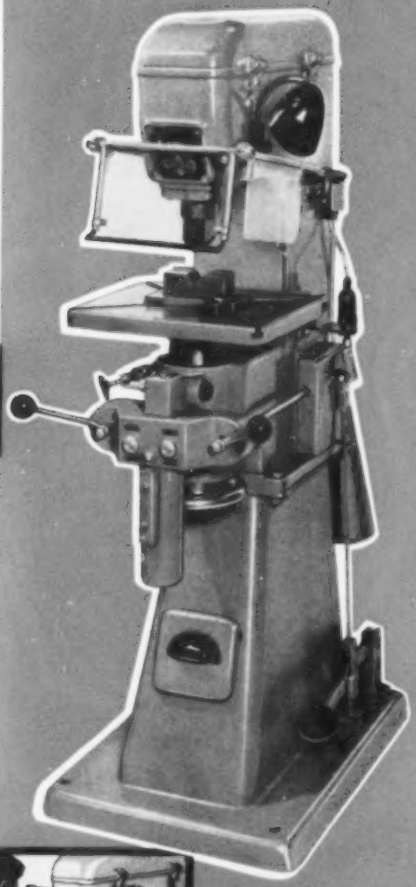


Have you a labour problem? . operators like the Burger PRESS



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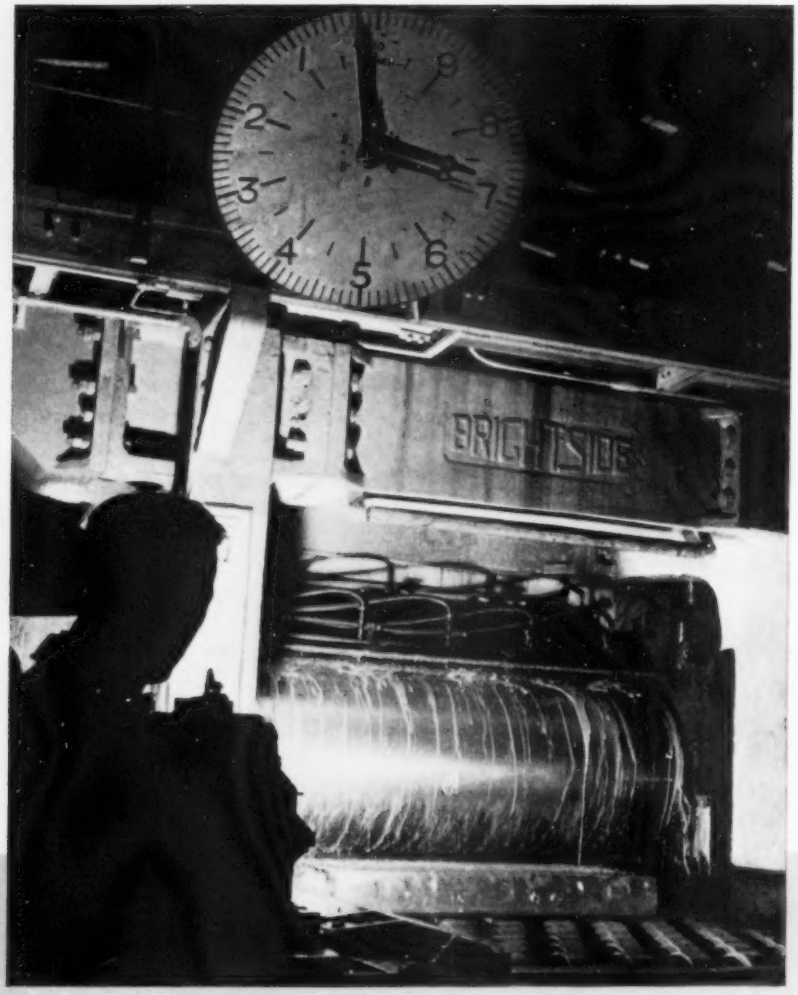

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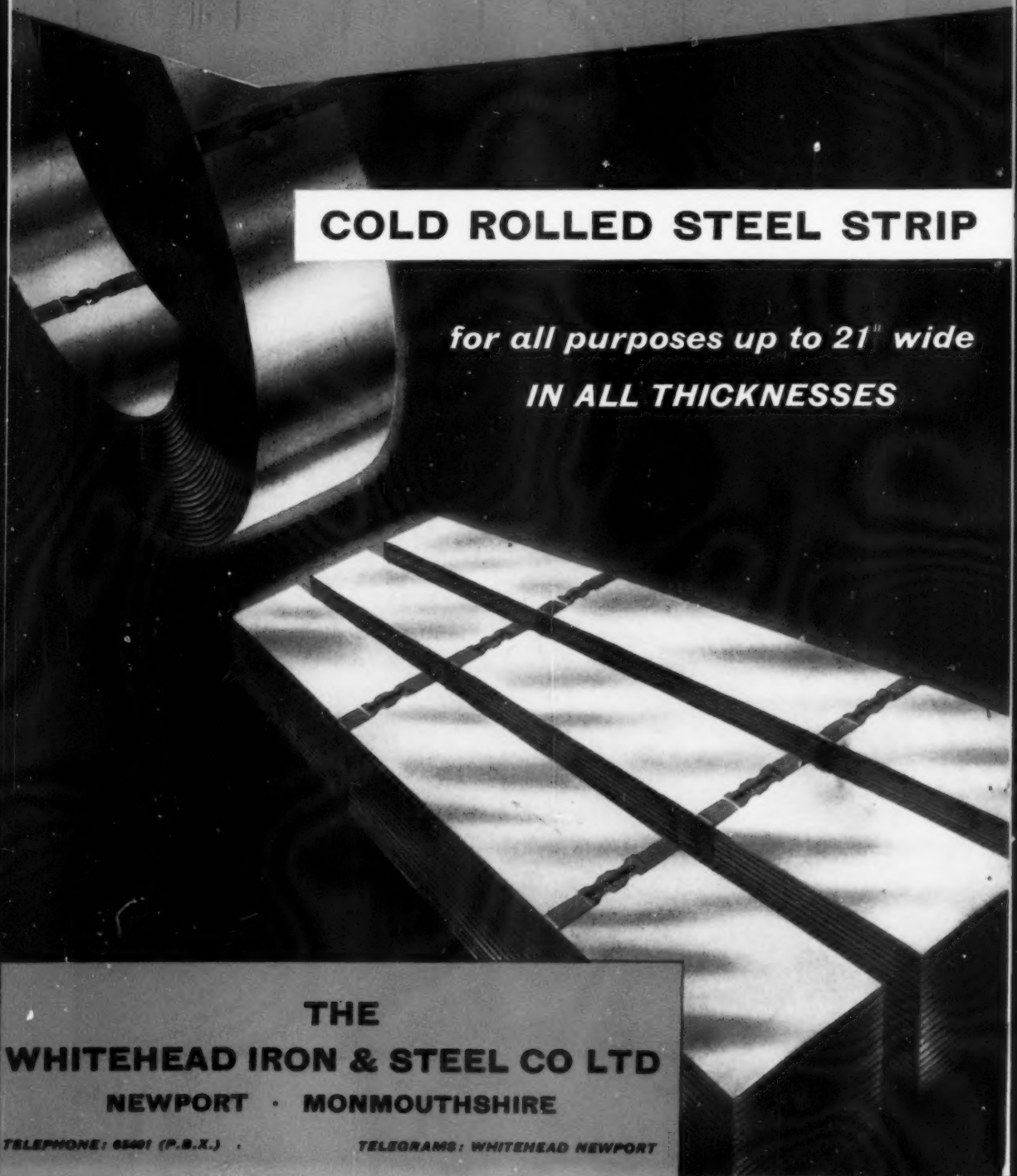

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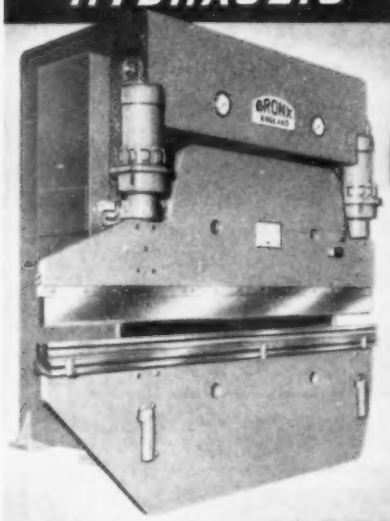

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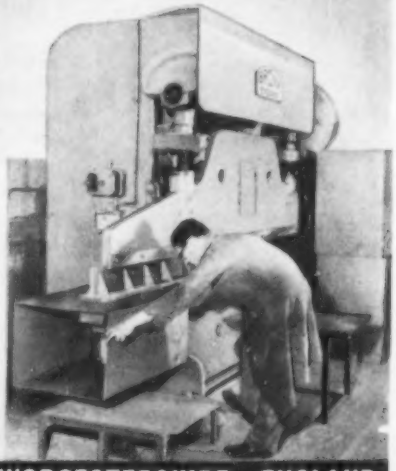

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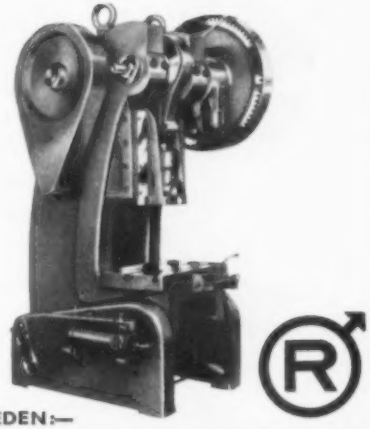

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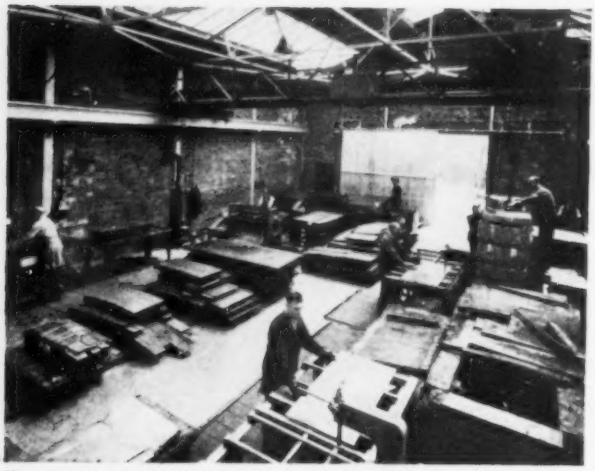

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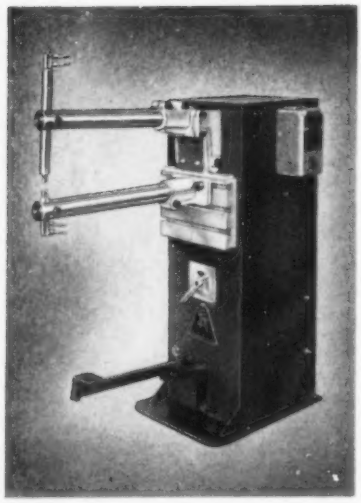

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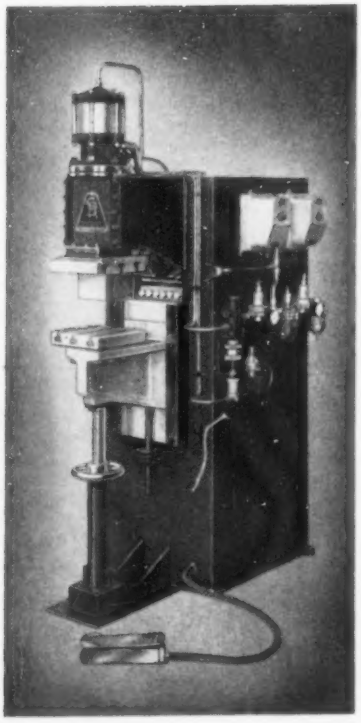
for all purposes



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Bottom left is shown an 80 K.V.A. combined Spot and Projection Welder. Other capacities available.

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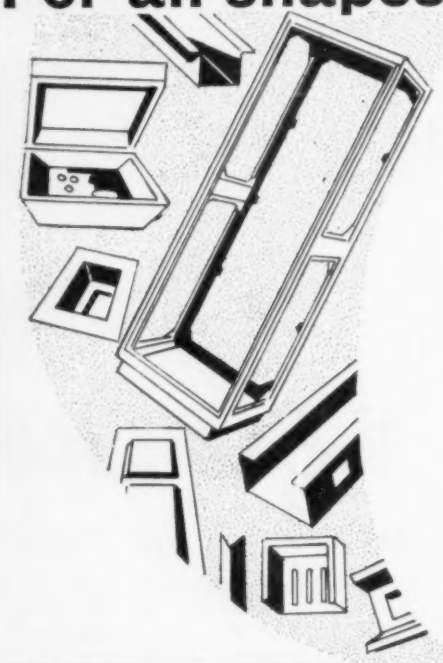

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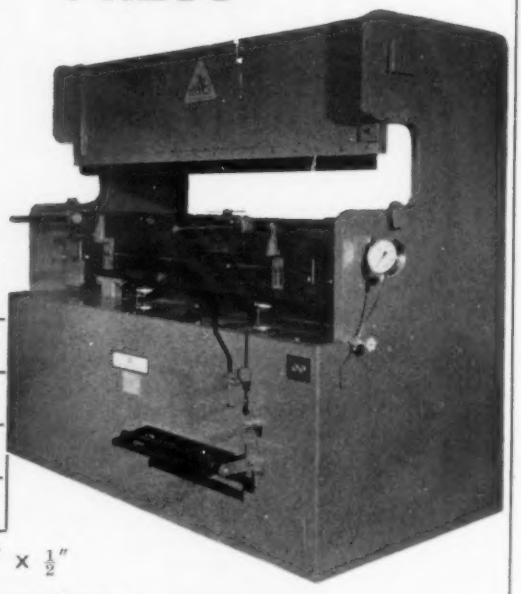

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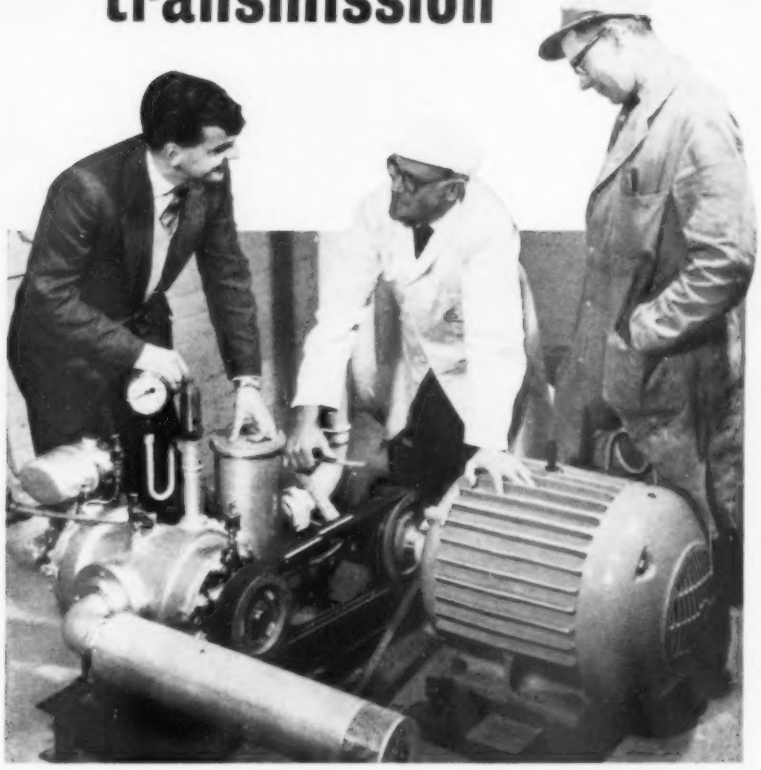

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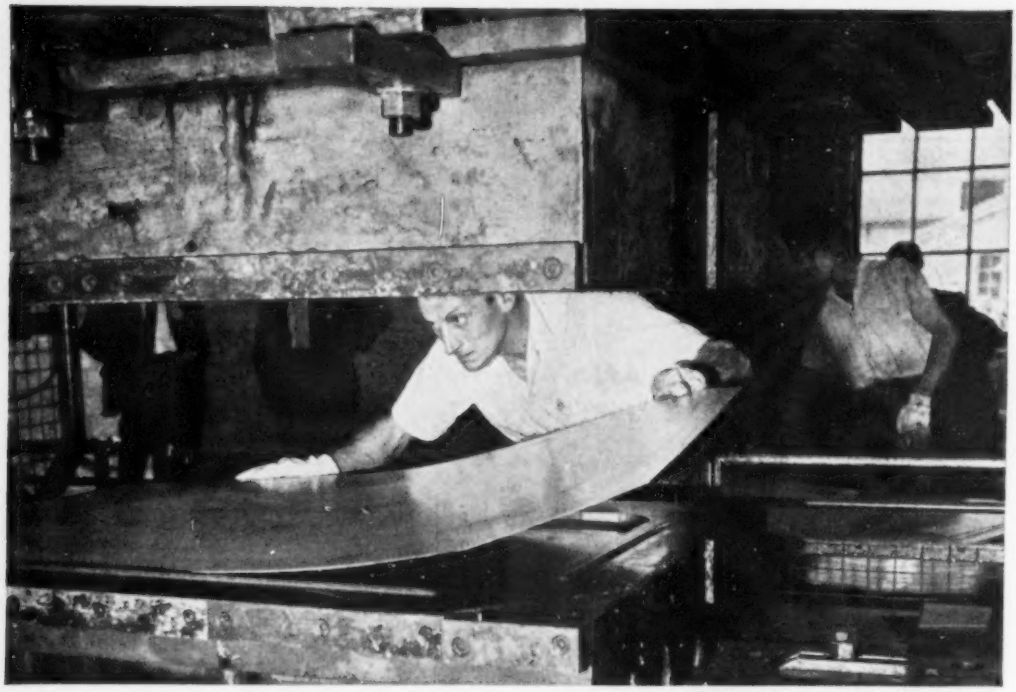

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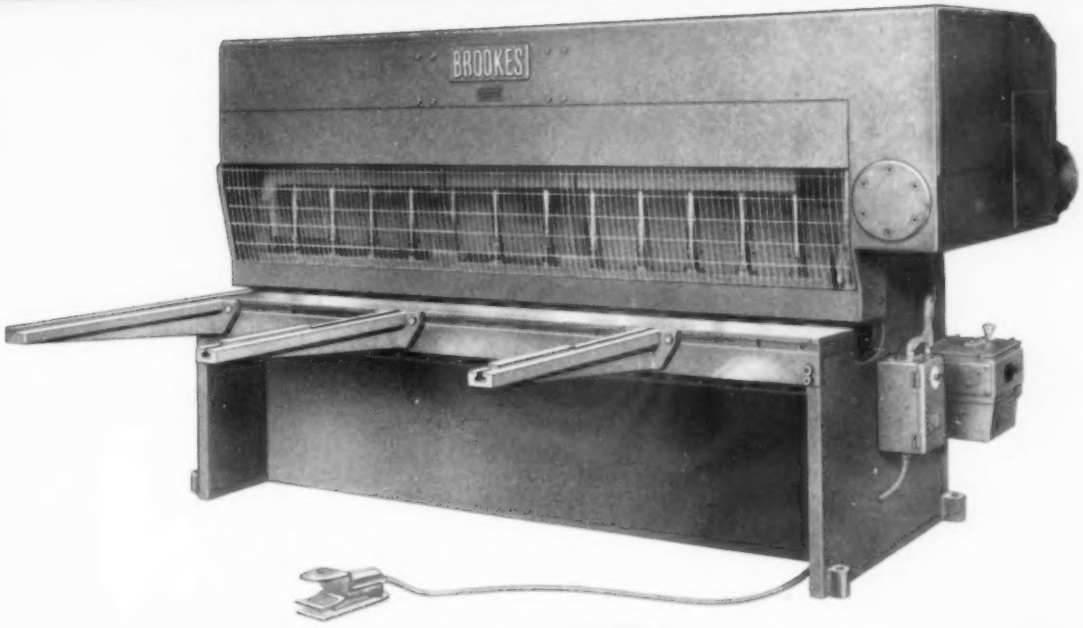

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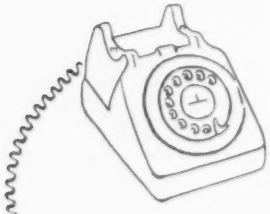

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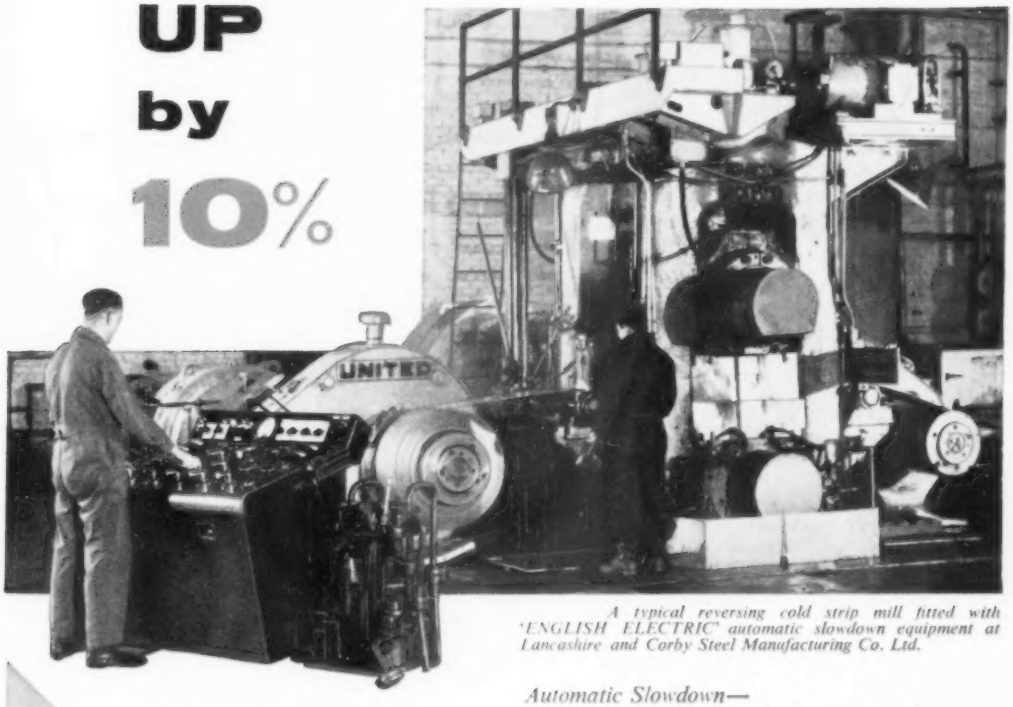

A typical reversing cold strip mill fitted with 'ENGLISH ELECTRIC' automatic slowdown equipment at Lancashire and Corby Steel Manufacturing Co. Ltd.

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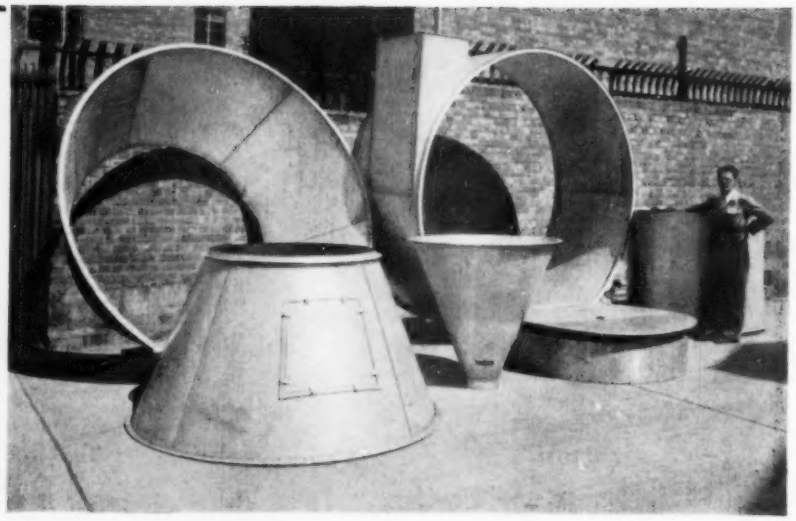

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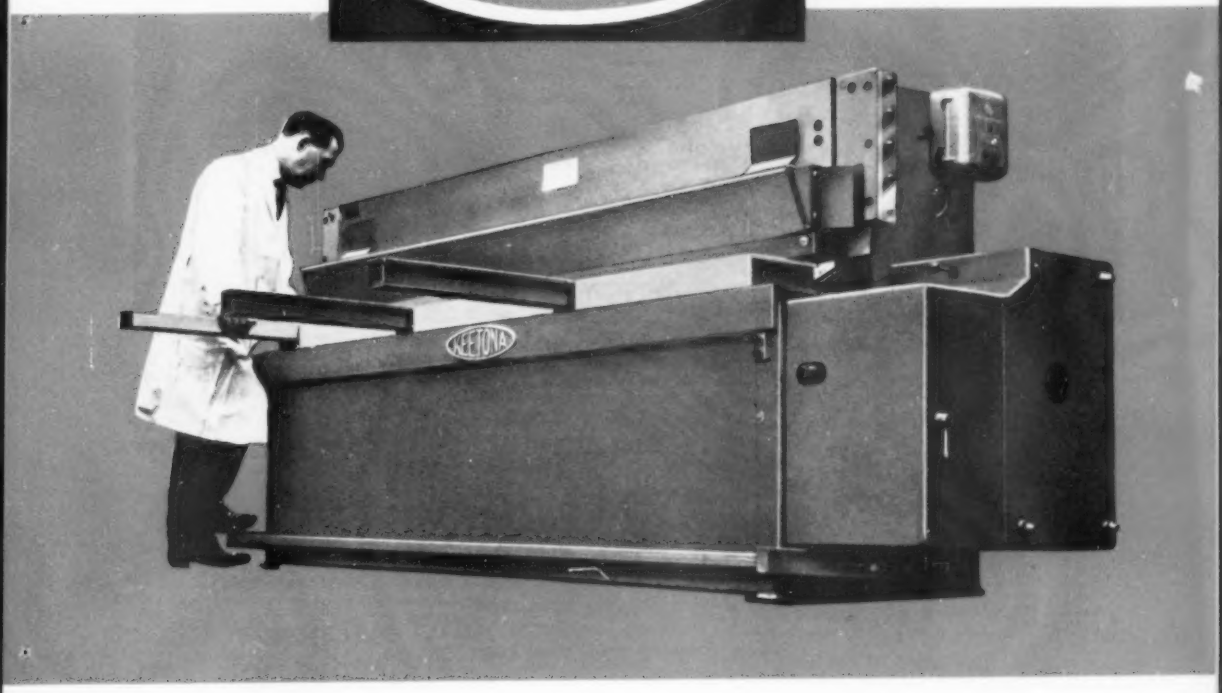

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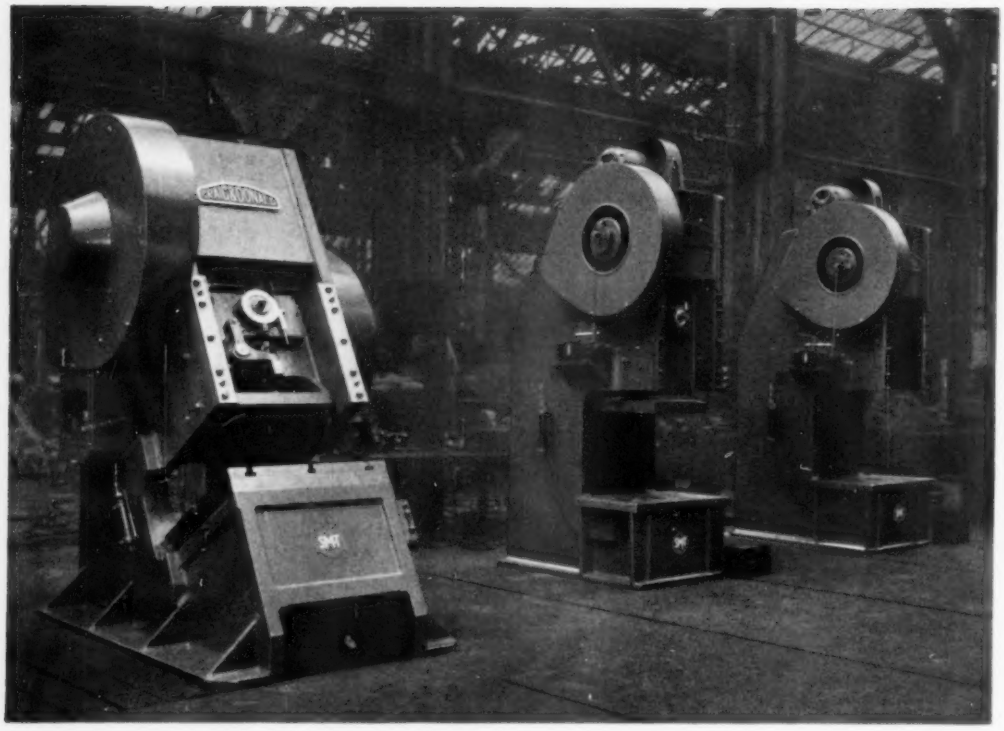

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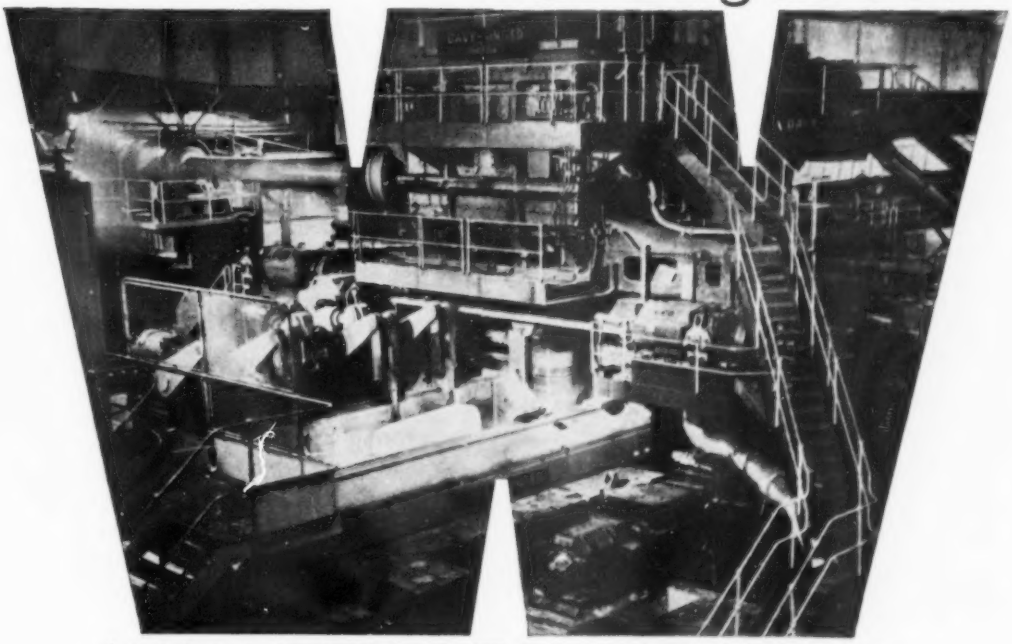

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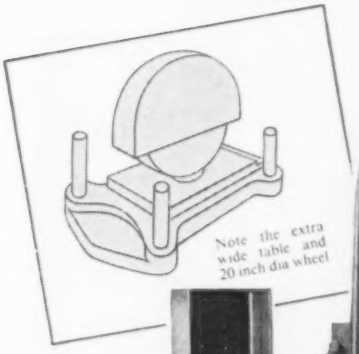

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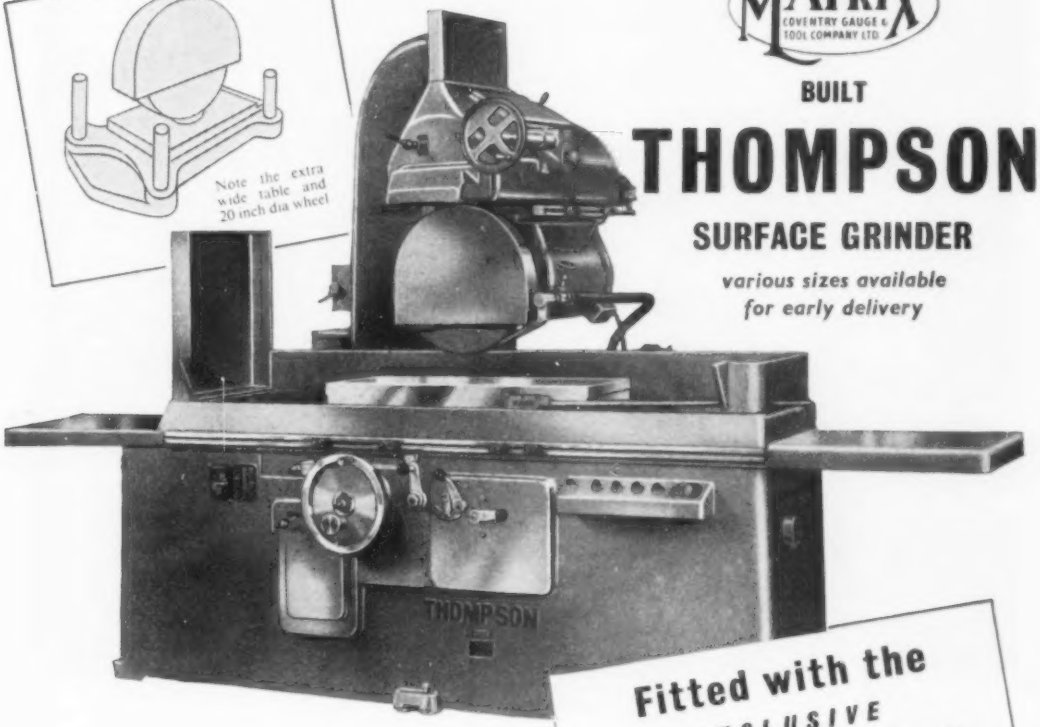

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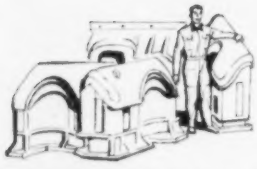

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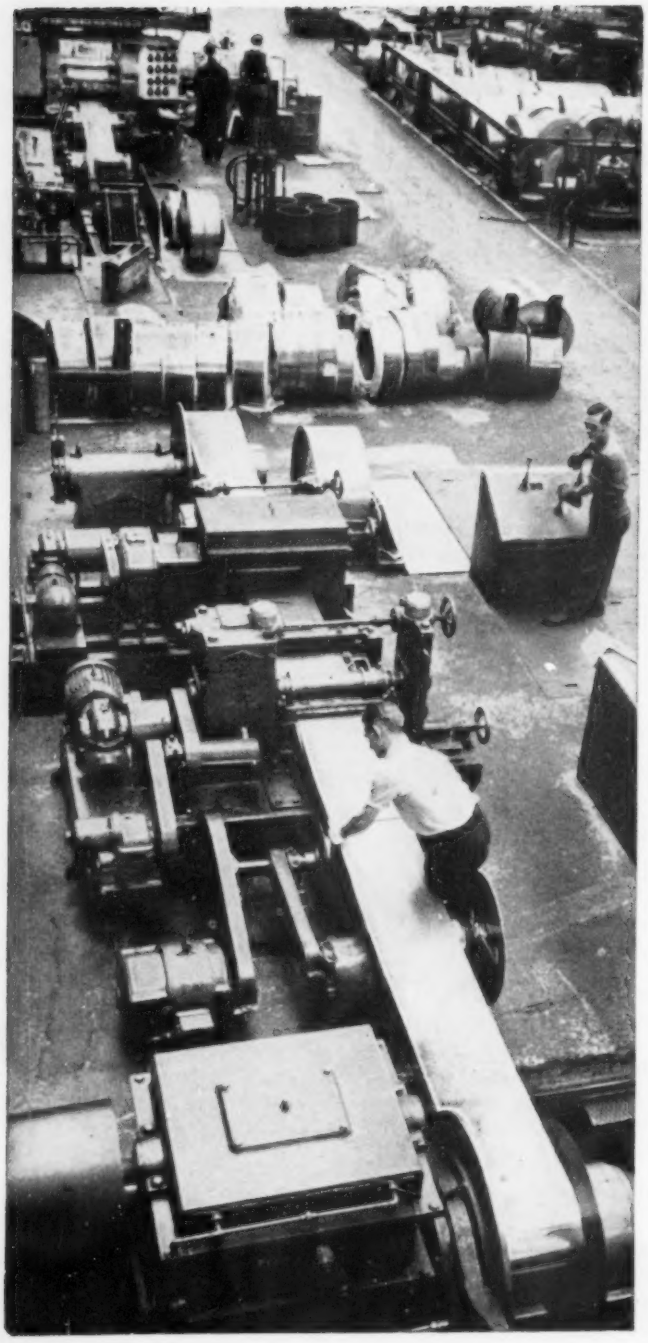

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MK2

STEEL-A RECORD YEAR

Biggest-ever output flows from Britain's busy furnaces

BRITAIN'S steel production in 1960 was the greatest ever recorded: over 24 million ingot tons. Output was running close to capacity in almost every section of the industry. Total production was *twenty per cent* above 1959.

Britain's capacity to produce steel has been increasing by leaps and bounds as a result of the £900 million which has been spent on three great development programmes. Last year alone the steel industry spent £130 million on development, *one-sixth* of all the money spent by manufacturing industry on capital investment in this country.

In the next four years the industry has already planned to spend another £450 million, and to raise its production potential by nearly one-third.

Another article on the opposite page describes a great new development in Scotland, which brings with it the promise of greater prosperity across the Border. Also in hand is a vast project near Newport, Monmouthshire. This is the Spencer works of Richard Thomas & Baldwins, which when completed will be Europe's most modern integrated steelworks. An enormous green-field site has been laid out, and work is going ahead at a tremendous pace.

Expansion under way

Three more new mills to roll improved and more efficient sections for building and constructional work will come into operation shortly at Colvilles, South Durham and the United Steel Companies.

Among the very large schemes announced in 1960 were the Tinsley Park scheme of the English Steel Corporation to increase their output of alloy and special steels, costing £26 million; the United Steel Companies' plans at Appleby-Frodingham and Samuel Fox, costing £32½ million; a Dorman Long plan costing £36 million; and the entirely new works at Rotherham of the Park Gate Iron and Steel Company which will cost £55-60 million.

Prospects for '61

What are the prospects for 1961? The industry will be able to improve on the 1960 record figure. Capacity in 1960 was nearly 26 million tons – this year it will be 27 million tons. All the time, the industry is expanding to meet future demand. This expansion is geared, not to any yearly fluctuations in our manufacturing activity, but to the steadily rising curve. It is in the confidence that this curve *will* go on steadily rising, that the many far-reaching development plans in steel are being pressed forward without slackening.

Exports a record too

Besides the enormous amount of steel which Britain exported last year in the form of manufactured goods, the steel industry's own direct exports of steel were booming.

Over 4 million ingot tons, valued at some £230 million, went into direct exports of steel in 1960 – a post-war record.

Latest available figures show that well over one-third of this went to Commonwealth countries: exports to the Commonwealth were 20% up on 1959 in tonnage. Tonnage of exports to Western Europe showed a similar upsurge. Exports to the Soviet Bloc including China, though small by comparison with total exports, also showed an increase.

Two new steels for supersonic flight

What will the supersonic airliner of the future be made from? Opinions are divided, but the Bristol T.188 research plane, which has been built to explore the problem of flight at speeds of the order of 1,800 m.p.h., is made from heat-resistant stainless steel to withstand the high temperatures caused by the friction of the air at such speeds.

The steel scientists of Sheffield have produced two new types of steel from the experience of the Bristol T.188. Although heat-resisting alloy steels had already been in use in jet engines for many years, these were not suitable for making large thin sheets of the kind required to build an airframe. The new steels produced in Sheffield are capable of being made in large sheets, and can be "worked" into the complicated shapes required.

New bridges hang on steel

The new road bridge over the Firth of Forth is being anchored into the solid rock with specially thick steel cables. They are 1¼ in. in diameter and have a breaking load of more than 350 tons. Over a thousand of these cables, enclosed in groups of four in 4½ in. diameter steel tubes, are embedded 240 feet into the rock. Other similar cables are being used to support the 110 ft. high towers until the main steel suspension cables are in position.

Other new bridges using steel suspension cables are planned over the Wye and Severn. Altogether some 70,000 tons of steel will go into the three bridges.

STEEL–THE YEARS AHEAD

New strip mill promises brighter future for thousands *BY MARGARET STEWART*

THERE is no problem of mass unemployment in Britain today as there was before the war. But there are still black spots. Scotland has 72,000 jobless, 3.3% of all its workers. In Greenock and Port Glasgow the proportion is as high as 8.1%. The national average is 1.6%.

New light industry has brought 50,000 jobs to the Clyde valley since the war. But Scotland is still over-dependent on heavy industry.

The steel industry is playing a vital part in redressing the balance, and bringing hope of an industrial renaissance. Colvilles, one of the leading British producers, are going ahead with ambitious plans to raise their steel-making capacity from 2·3 to 3·3 million tons a year. Their most important and imaginative project will produce 500,000 tons of steel sheet and 175,000 tons of light plates a year. It is in two parts – a hot strip mill at Ravenscraig and a cold reduction mill at Gartcosh, 8 miles away.

This is a completely new development for Scottish industry, traditionally a user of heavy steel. The Scots hope that plentiful supplies of sheet steel will attract manufacturers of cars, car accessories, refrigerators, washing machines, cookers, and office furniture. A canning industry could follow. Rootes and the British Motor Corporation have already decided to go north.

Snowball effect

Sir Andrew McCance, chairman of Colvilles, told me: "But for the strip mill, these motor car firms would not have elected to come to Scotland. They will bring a lot of ancillary trades, and the cumulative effect is bound to be substantial."

Mr. John Lang, steel union leader, chairman of the Scottish Board for Industry, and treasurer of the Scottish TUC, said there had been many encouraging enquiries.

The Government's decision to lend Colvilles £50 million for Ravenscraig caused controversy in Parliament. Labour spokesmen said it was wrong to use public money for the benefit of shareholders. Conservative back-bench MPs attacked the loan as "bastard socialism".

But the Scot-in-the-Street was spoken for by Mr. Lang: "We don't care a damn where the money comes from, so long as our men don't have to walk the streets looking for jobs."

Plans are going ahead in spite of the recession in the car industry. What extra employment will result? Perhaps another 1,500-2,000 steel workers will be needed. The car developments should provide upwards of 10,000 jobs directly. The Pressed Steel Company is expanding its plant near Paisley to produce bodies for cars and commercial vehicles. A new development by the accessory firm of Rubery Owen, scheduled for Bathgate, will mean work initially for about 200. And there will be a "snowball" effect from these developments within the next few years.

MARTIN: "A dandy layout"

100% success

It was stimulating to visit the Ravenscraig and Gartcosh sites. The men on the job impart their own infectious enthusiasm.

William Banks, general manager of Ravenscraig, has watched its progress for three years. "I have a great deal of faith in the future of the steel industry, and of our company in particular," he said. "I believe we shall have 100 per cent success."

More steel-making capacity is being installed to supply the new mill. Ravenscraig will be one of the first large plants in this country to adopt the "L.D.-A.C." process, one of the most modern and economic methods of making steel, using oxygen and lime.

About two-thirds of the output of the hot strip mill will be sent to Gartcosh to be cold-rolled into high quality sheet.

There is a strong reason for building at Gartcosh. Nine hundred men work there in the old hand mills of Smith and McLean. Their livelihood depends on steel.

Progress at Gartcosh, as at Ravenscraig, is well up to schedule. George Martin, the "boss", told me that American experts to whom he showed the plans had commented, "That's a dandy layout."

At first 500 men will be employed, rising to 1,000. Most of Smith and McLean's men will be found work. "We will go out of our way to place them in suitable jobs," I was told.

The two men who will manage the hot and cold strip mills are both in their early thirties. James Watson, manager-designate of the hot strip mill at Ravenscraig, is 34. His opposite number at Gartcosh, James Easton, is 31. Both have been through Colvilles' 'sandwich' courses at the Glasgow Royal College of Science and Technology. Both are brimful of confidence in themselves, their industry and the future of Scotland.

WATSON: "Finest thing that ever happened"

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The articles on these two pages form part of an advertisement published in the Press by the British Iron and Steel Federation

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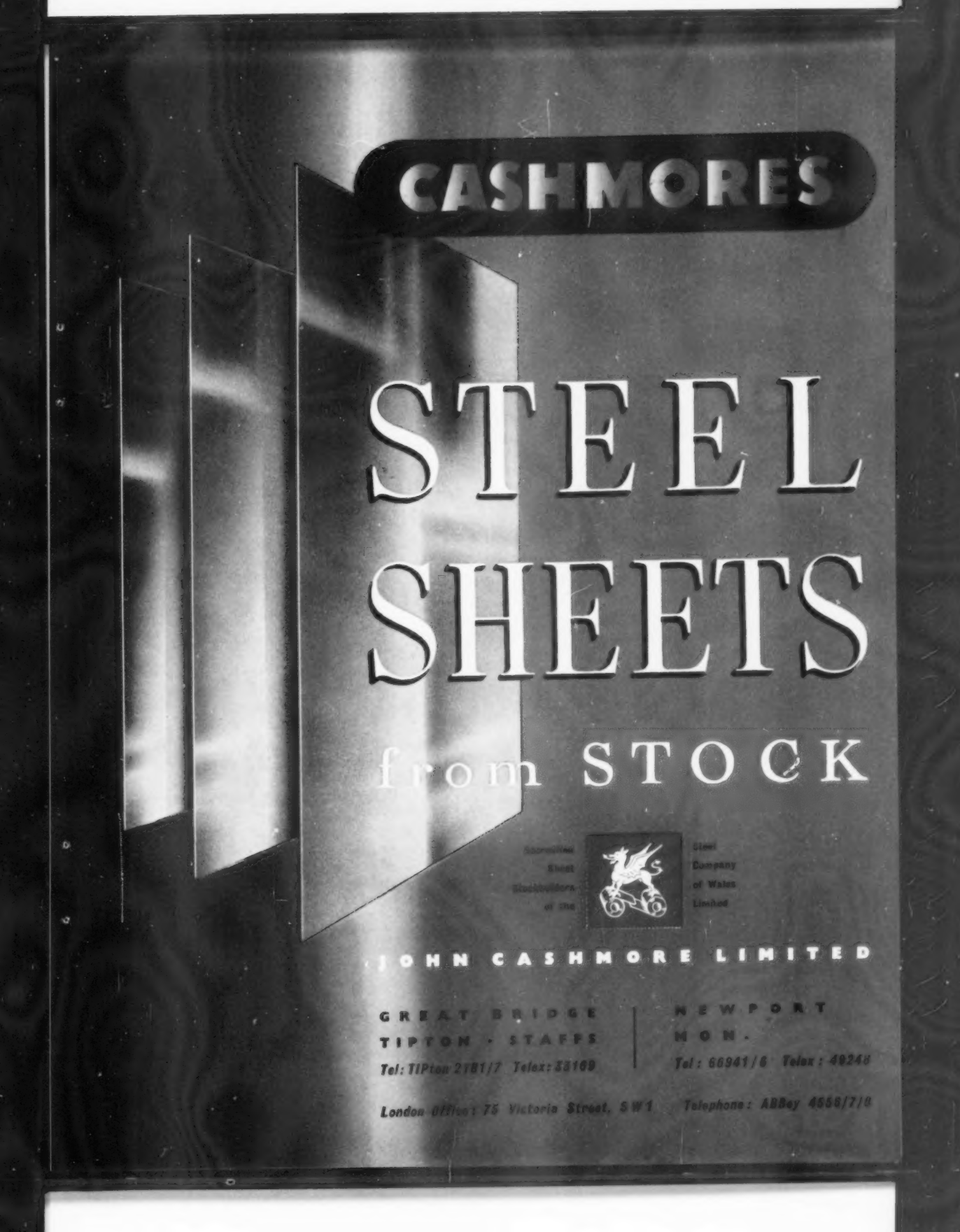
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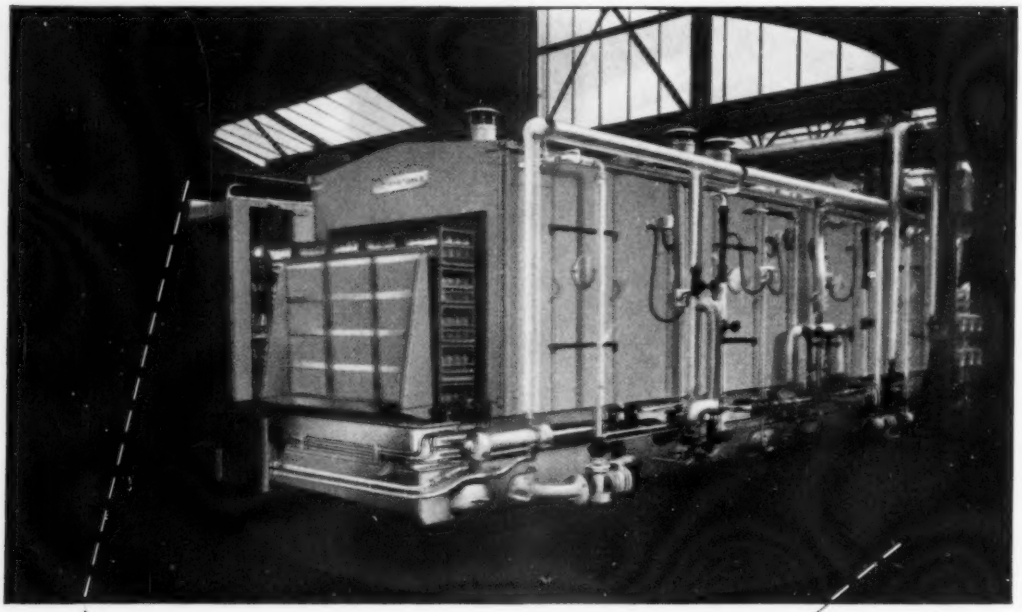

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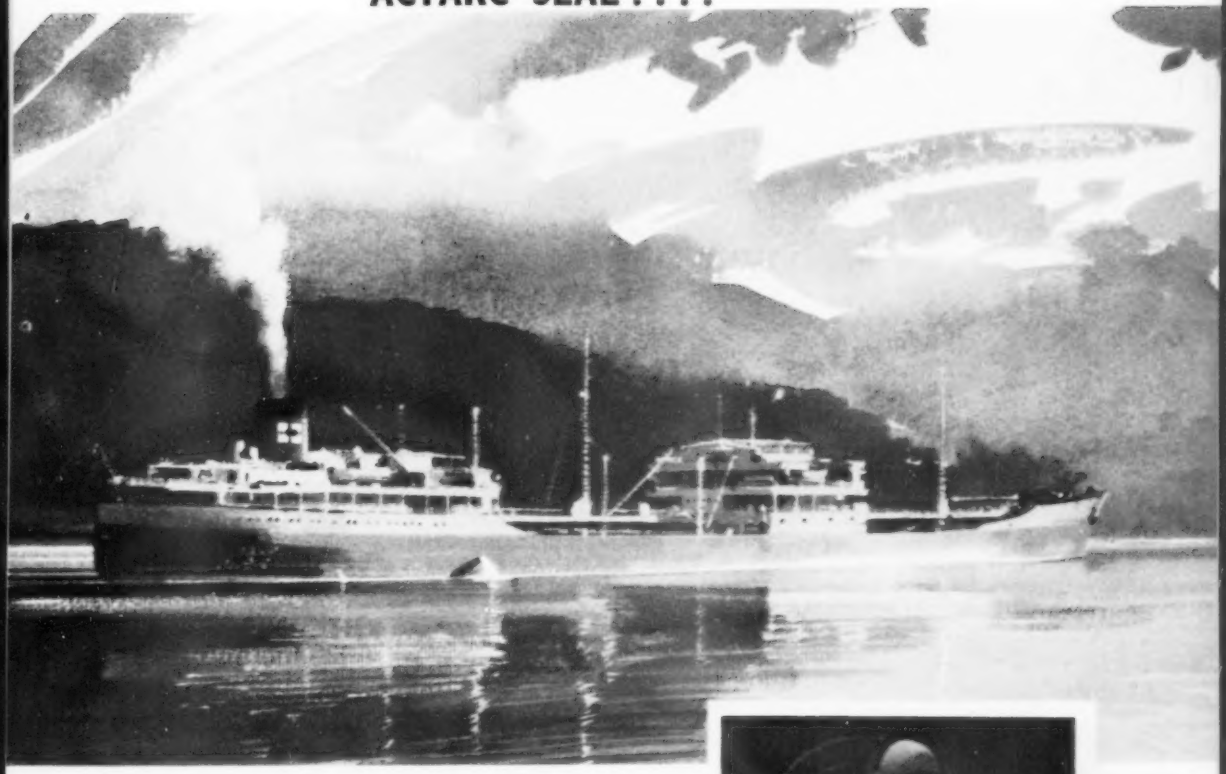

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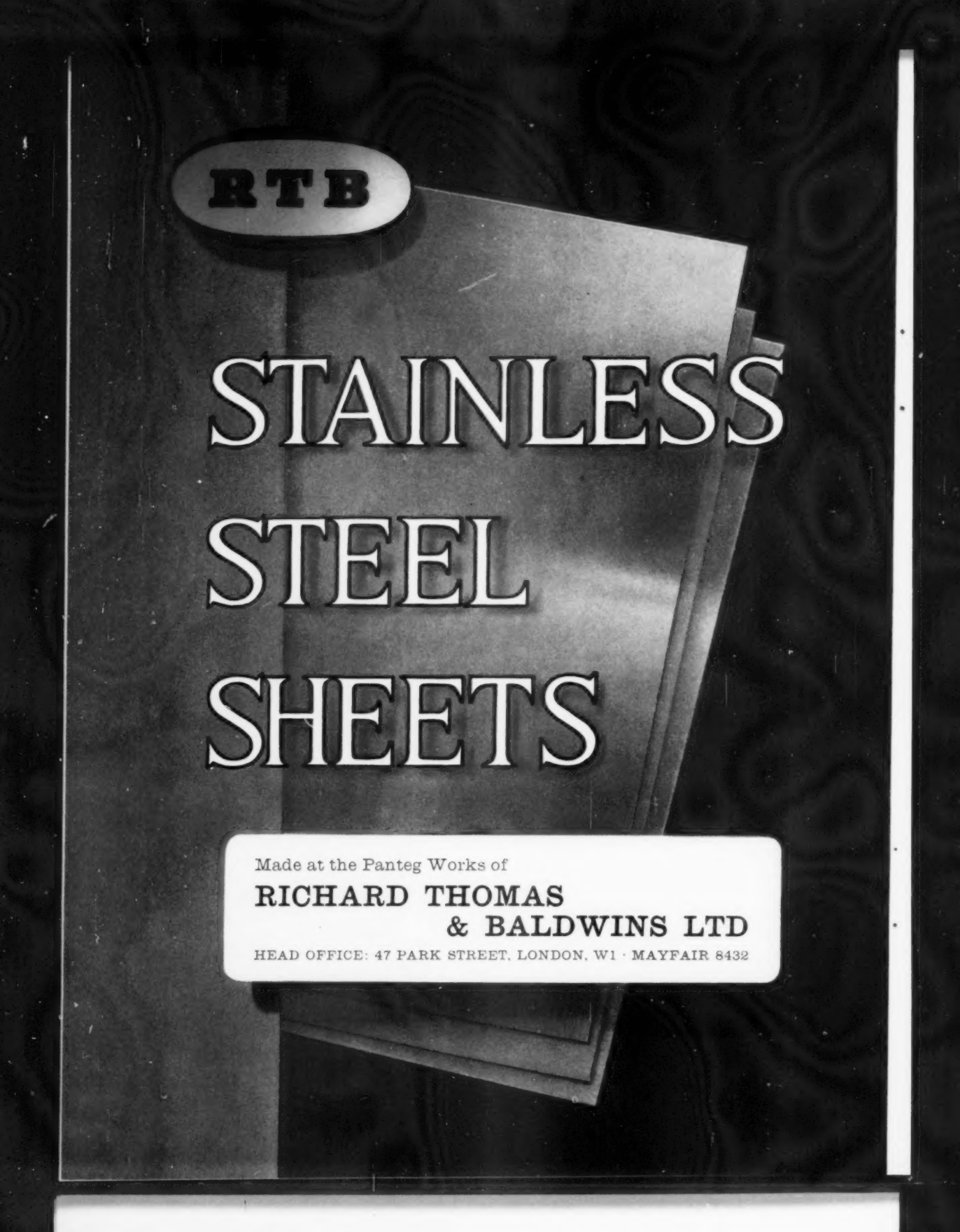
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Production Procedures at the Beacon Works of John Thompson Motor Pressings Ltd.—4 82
This is the fourth article in a series describing typical techniques used by John Thompson for the production of a wide range of components. The company are world-renowned for their major contributions to developments in the motor-car industry and it is this aspect of their production that has been highlighted in this series. This article describes the production of the main components for the body of the Austin-Healey "Sprite." Some interesting pressing and welding operations are involved, and tool drawings and photographs of production stages are included. Full details of the final assembly sequence will be given in next month's issue.

The Welding of Aluminized Steel Sheet 95
T. M. Molossi, B.A., and John H. Nicholls, A.R.I.C.
Aluminized steel has high corrosion resistance and the ability to withstand high service temperatures for considerable lengths of time. For the guidance of fabricators who have, so far, had no experience of welding this material, the authors, who are on the staff of Coated Metals Ltd., manufacturers of ALUDIP aluminized steel sheets, give data and information obtained from trials and experimental work on the resistance and fusion welding of the material carried out by the British Oxygen Co. Ltd., and Sciaky Electric Welding Machines Ltd. Reference is made to spot welding, projection welding, seam and stitch welding, resistance butt welding, brazing and argon-arc fusion welding.

Tooling for Cold Extrusion 99
R. A. P. Morgan, O.B.E., M.I.Mech.E., W. S. Ketchin and A. E. Walmsley
As the tools used for cold extrusion have to withstand repeated high stresses, in order to give a good tool life every effort has to be made to reduce the complexity of stress, and keep, if possible, the tools under compression. This paper from the Royal Ordnance Factory at Birtley, which was presented at the recent Institute of Sheet Metal Engineering Conference on the cold extrusion of steel, gives information on extrusion-die design, steel inserts, tungsten-carbide dies, lubrication of tools, punch design (results shown by photo-elastic studies), tool steels and heat treatment, deviation of components from tool dimensions and tool costs and expected life. Illustrated by many drawings and photographs this informative paper is followed by the discussion which ensued after its presentation at the Conference.

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Cold Forming of Steels 123
F. Griffiths
This paper was also presented at the Institute of Sheet Metal Engineering Conference on the cold extrusion of steel and is published, together with the discussion that ensued following its presentation. The author, who is chief production development engineer of the British Motor Corporation, describes the conclusions he has reached in the process from the point of view of producing components for his own particular industry. He makes some interesting remarks on the design of presses he requires and gives information on the wide variation in price quoted for a specially designed press from five different press manufacturers. Various typical components and their production stages illustrate the paper.

An Introduction to the Theory and Practice of Flat Rolling—6 135
The late C. W. Starling, B.Eng., A.M.I.Mech.E.
The effect of mill spring on gauge is the main theme of this chapter of the late author's book (which will be published after serialization in "Sheet Metal Industries" by the University of London Press Ltd.). The main subject is reviewed under the headings of mill modulus, modulus of rolls and housing, the elastic/plastic curve, the roll-gap transfer function, the effect of mill stiffness on gauge and on the automatic control of gauge, and mill spring and taper rolling.

Sheet Metal Data Sheet—14. Manufacture of Tin Boxes (2) ..... facing page 142
This is a further data sheet in the series specially compiled for "Sheet Metal Industries" by J. W. Langton, M.B.E., B.Sc. (Lond.), M.I.Mech.E.

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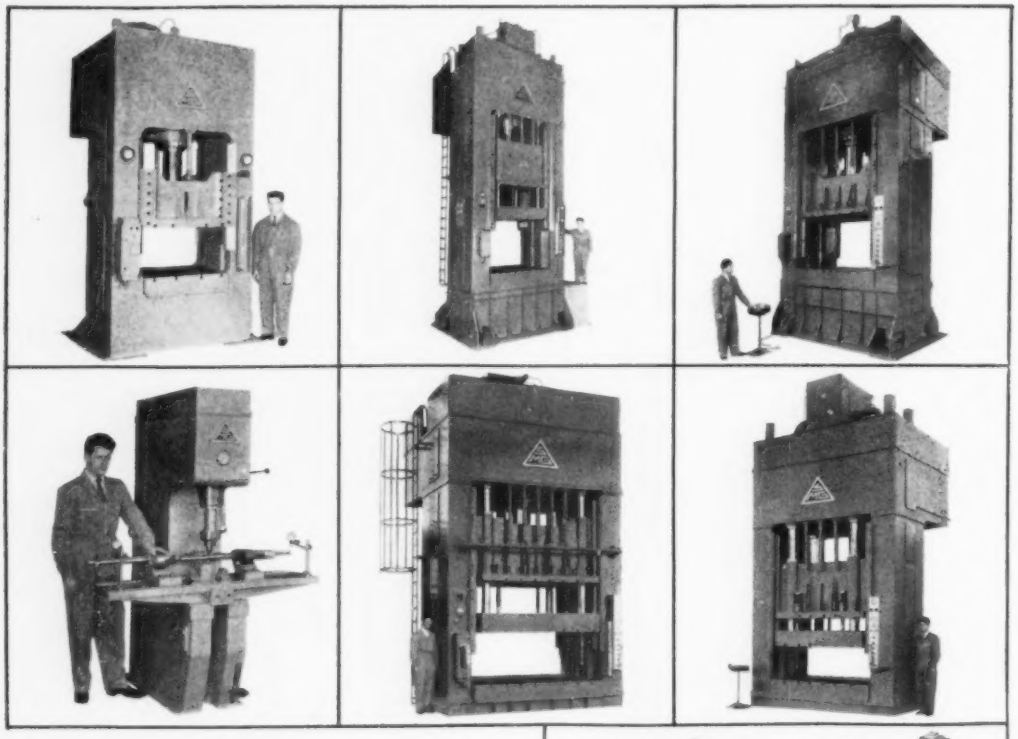

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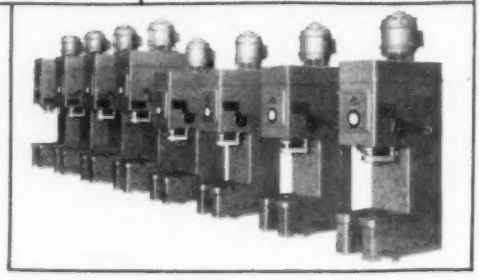

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La Soldadura de Chapa de Acero Aluminizado .. pagina 95

Por T. M. Molossi, B.A. y John H. Nicholls, A.R.I.C.

El acero aluminizado posee una alta resistencia a la corrosión y la capacidad de resistir altas temperaturas de trabajo durante largos periodos. Como guia para los elaboradores que hasta ahora no han tenido experiencia en la soldadura de este material, los autores, que forman parte del personal de Coated Metals Ltd., fabricantes de las chapas ALUDIP de acero aluminizado, ofrecen datos e información obtenidos como resultado de pruebas, ensayos y trabajos experimentales sobre la soldadura por resistencia y por fusión del material, llevados a cabo por la British Oxygen Co. Ltd. y la Sciaky Electric Welding Machines Ltd. Se hace referencia a la soldadura por puntos, soldadura por resistencia con salientes, soldadura de costura y de puntos, soldadura a tope por resistencia, soldadura fuerte y soldadura por fusión al arco de argón.

Herramientas para la Extrusión en Frío .. .. pagina 99

Por R. A. P. Morgan, O.B.E., M.I.Mech.E., W. S. Ketchin y A. E. Walmsley

Como las herramientas que se emplean para la extrusión en frio han de resistir grandes esfuerzos repetidamente, para lograr que tengan una buena duración, se ha de procurar por todos los medios reducir la complejidad del esfuerzo y mantener, siempre que sea posible, las herramientas bajo compresión. Este trabajo, presentado por la Real Fábrica de Armamentos

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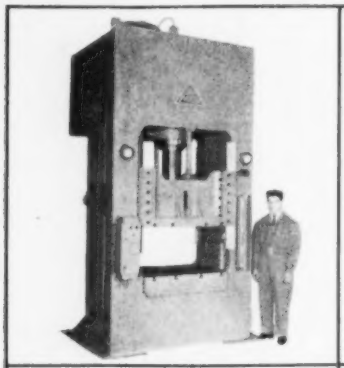

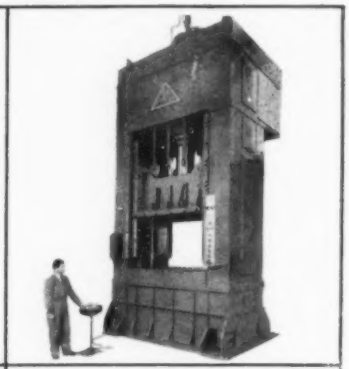
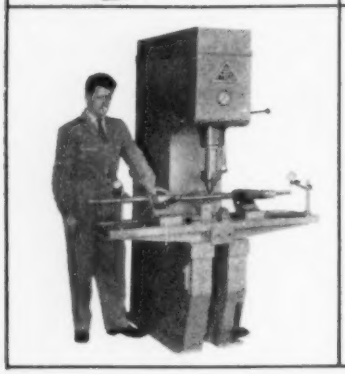
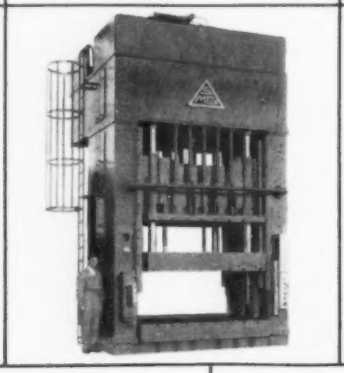
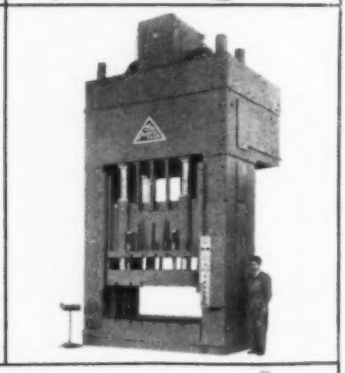

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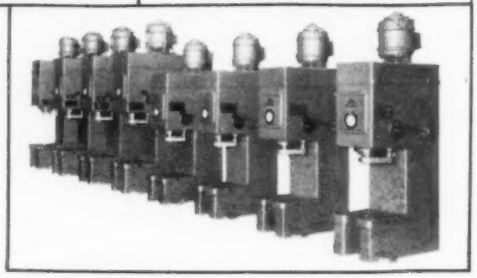

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La Soldadura de Chapa de Acero Aluminizado .. pagina 95

Por T. M. Molossi, B.A. y John H. Nicholls, A.R.I.C.

El acero aluminizado posee una alta resistencia a la corrosión y la capacidad de resistir altas temperaturas de trabajo durante largos periodos. Como guía para los elaboradores que hasta ahora no han tenido experiencia en la soldadura de este material, los autores, que forman parte del personal de Coated Metals Ltd., fabricantes de las chapas ALUDIP de acero aluminizado, ofrecen datos e información obtenidos como resultado de pruebas, ensayos y trabajos experimentales sobre la soldadura por resistencia y por fusión del material, llevados a cabo por la British Oxygen Co. Ltd. y la Sciaky Electric Welding Machines Ltd. Se hace referencia a la soldadura por puntos, soldadura por resistencia con salientes, soldadura de costura y de puntos, soldadura a tope por resistencia, soldadura fuerte y soldadura por fusión al arco de argón.

Herramientas para la Extrusión en Frío .. .. pagina 99

Por R. A. P. Morgan, O.B.E., M.I.Mech.E., W. S. Ketchin y A. E. Walmsley

Como las herramientas que se emplean para la extrusión en frío han de resistir grandes esfuerzos repetidamente, para lograr que tengan una buena duración, se ha de procurar por todos los medios reducir la complejidad del esfuerzo y mantener, siempre que sea posible, las herramientas bajo compresión. Este trabajo, presentado por la Real Fábrica de Armamentos

(Continuará en p. 148)

SHEET:

STRIP:

PLATE:

EXTRUDED SECTIONS,

ROD & BAR:

TUBE

FORGINGS

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ANT OR GRASSHOPPER

IF evidence were needed that the fundamental nature of Man has signally failed to modify itself in line with changes and developments in his knowledge of and control over his material environment, it could be readily obtained from a study of the writings of the sages of the pre-Christian era. A study of human foibles and failings such as inspired, for example, the Analects of Confucius or the Fables of Aesop reveals that today, centuries later, the mainsprings of human action are basically unaltered.

Naturally, the scale has changed. Had St. Paul had available to him the modern means of travel and mass propaganda his lengthy journeyings to spread the Gospel would have been far less hazardous, albeit possibly far less fruitful as well. And therein lies the rub. Anyone with sufficient funds at his disposal can today preach, in a comparative instant of time, what gospel he pleases, whether it be a great spiritual truth, a greater political untruth, or merely the virtues of his own brand of detergent, to a congregation outnumbering by millions those whom the early teachers were able to influence in a lifetime of travel and exhortation. As a consequence of the all too ready availability of mass media of communications, the impact of the spoken and written word has been dulled and the discriminatory power of the hearer or reader blunted by the surfeit.

This is a truly sorry state, for from time to time it is necessary that a particular message shall carry conviction in order that the course of events may be influenced in a desired direction. Of such a nature is the present need to increase the sales of this country's manufactured products and capital goods in those countries from which we must perforce buy materials for their manufacture. One would have thought this need would have been so self-apparent as to need none of the machinery of propaganda to illuminate its truth, but such is evidently not the case.

Similarly, as we remarked in this page last month, one of the few natural resources available in this country is the high potential quality of scientific and technical talent of its natives. It would therefore be reasonable to suppose that no effort would be spared to develop this invaluable potential to the utmost extent, and secure for our science and industry the services of the greatest possible number of people, trained to the most effective pitch.

There would appear to be some danger in the cases of both exports and technical education that the fact that the problems are being widely and loudly discussed is an indication of equally forthright and widespread action. This is far from being the case and the Chancellor of the Exchequer had to have recourse to Aesop recently to emphasize that the world does not owe us a living. On the contrary much of the world is diverting many of its energies to acquiring a greater share of our living—at our expense. The grasshopper undoubtedly had the best of the summer, but the ant was the one who weathered the chill of winter.

Production Procedures at the Beacon Works of

JOHN THOMPSON MOTOR PRESSINGS Ltd.

Fabricating the Austin-Healey "Sprite" Underbody: Part 1

Designed by Donald Healey, the Austin-Healey "Sprite" is the smallest sports two-seater car in quantity production by any of the larger British car manufacturers. Of chassisless design, the body shell forms the structural framework of the car, an unusual feature in a sports car, and it is this aspect of the vehicle that is of great interest.

John Thompson Motor Pressings Ltd., are responsible for the production of the underframe unit which incorporates over 50 components of varying sizes and in thicknesses from 21-gauge to ¼-in. plate.

An open body of this type which lacks the roof and door pillars of the saloon, must incorporate members designed and positioned to impart the necessary stiffness. The floor of the Sprite is a single-sheet below propeller-shaft level and practically flat except for shallow sloping depressions at the front which form foot wells, and two sets of four pressed-in ribs, one on each side of the propeller-shaft tunnel at the rear. Across the centre of the floor pressing and welded to it is a top-hat-section cross-member which extends for the full width of the floor; this member incorporates outwardly turned flanges on each end (Fig. 62).

Tubes that afford jacking points are mounted in each end of the cross-member; these tubes protrude through the body sill inner panels, each of which is welded to the upturned edge of the floor pressing.

The floor pressing is cut away to clear the gearbox in front of the cross-member and on each side of this opening a longitudinal top-hat member is welded both to the floor and the cross-member. These longitudinal members (the main beams) extend from the centre cross-member forward of the floor and carry the engine unit, etc.

Underneath the overhanging part of each of these members is welded a flat closing plate and the box-section arms thus formed are bridged near their front ends by a wide shallow box section also formed by a top-hat section on to which a closing plate is welded.

In line with this bridge member are welded the abutment brackets for the front springs, the welding being to the outer faces of the longitudinal members. The brackets are stiffened by a member of channel section positioned transversely above the cross-member. To the front and rear lower edges of the abutment brackets are welded the pivot brackets for the front wishbones, and to the outer faces of the

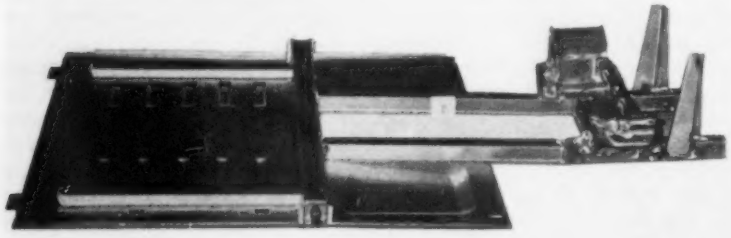

Fig. 62.—General view showing floor panel complete with centre cross-member, longitudinal stiffeners, main beams (1), front crossmember and front-suspension assembly and radiator brackets

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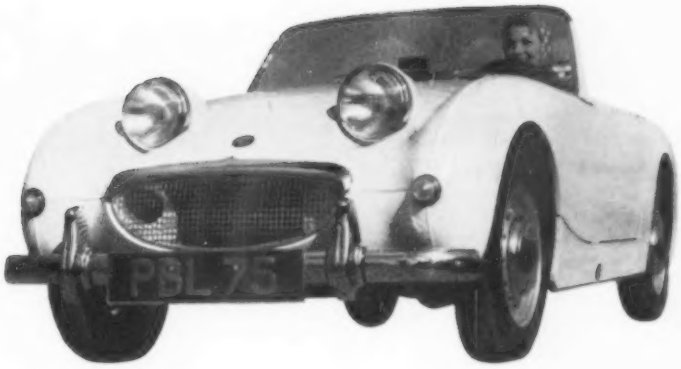
(*Series continued from page* 885, *December*, 1960)



longitudinals, slightly ahead of the abutment brackets are vertical angle-section pressings for carrying the radiator assembly. A right-angle stay of channel section is bolted to the inner side of each front-wheel arch and to a bracket on each side of the radiator.

Three components form each front wheel arch mounted above the brackets mentioned above. Of the three components, inner, top, and outer, the outer rear edge is welded to the front edge of the body sill side panel. Other assemblies include those that surround the passengers' legs and feet ; each consists of inner and outer side panels and a third pressing which forms the top and front. In fact the front of this assembly forms the rear of the front wheel arch. These two assemblies, together with a fabricated bridge member which joins them, form a rigid dashboard structure.

An arched-shape flanged pressing is welded to the floor assembly immediately ahead of the main cross-member, behind which the two-piece transmission tunnel assembly is welded to the floor panel between the two groups of four pressed-in ribs previously mentioned. The front part of the tunnel mates with the arch-shaped pressing and is domed to clear the top of the gearbox ; it locates partly on the cross-member. The rear end of the transmission tunnel is a flanged pressing of inverted U-section.

The rear cross-member is an inverted truncated U-section, deeper than the rear part of the tunnel. The shaped cut-outs on this member fit over the rear end of the tunnel ; the cut-outs are flanged on their edges and are welded to the tunnel. The cross-member lower edges are also flanged and are welded to the floor panel. The depression shown midway along the rear edge of the floor panel gives clearance for the propeller shaft. Various other channel sections, plates, etc., are attached by welding to appropriate points on the underfloor to give the necessary stiffness where required.

UNDERBODY PRODUCTION

The "Sprite" underfloor, as stated earlier, consists of over 50 major components and therefore it is not possible to describe the production of all of them ; the following description gives details of the most interesting operations involved and some information on the general assembly sequence, breakdown of sub-assemblies and details of sub-assembly operations, etc.

The majority of the blanks of medium-size required for the various components are produced in 500-ton Wilkins and Mitchell presses provided with automatic tray-type unloaders, the tools being designed to retain blanks in the die portion until the unloading tray is in position and then transferred to suitable cradles which are then removed to storage or to the next operation on fork-lift trucks.

As with many of the complete assemblies produced by John Thompson Motor Pressings, a number of the components for the "Sprite" are produced by the Group subsidiary company, Beacon Windows Ltd.

General Assembly Sequence in Brief

Assembly, in general, is by resistance welding the majority of the machines and jigs used being manufactured by the British Federal Welder and Machine Co. Ltd.

The wheel arches are built up in master jigs and the dash assembly is partially built first by assembling the two end boxes which are then joined by the heater platform. The side panels are left off.

The transmission tunnel is joined to the previously sub-assembled gearbox cover which is then attached to the rear crossmember in a jig by spot welding using pincer guns.

The inverted truncated U-section rear cross-member is assembled with the appropriate spacers in between.

The floor panel is placed in a special jig which comprises a main base with copper-bar-type

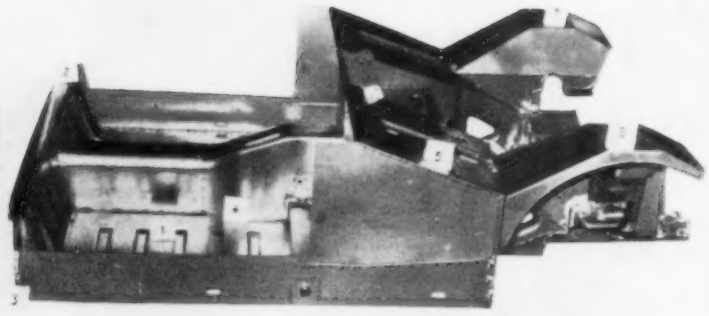


Fig. 63.—General view of completed underbody assembly, showing wheelarches (6 and 7), tunnel and gearbox cover assembly (4), and footwell assembly (5)

electrodes, and two swinging arms carrying the positive electrodes are used for spot welding. This machine enables one man to work from each side of the fixture, thereby obtaining maximum output. Additions made to the floor panel include main sidemembers, seat runners (complete with nuts), front longitudinals (main beams), tunnel stiffener to clear prop. shaft depression, main crossmember and various top-hat sections, etc. The jig incorporates a plastic frame to guide the welding head where items are attached to the underside and cannot be seen.

The rear crossmember and tunnel assembly are jigged and spot welded using pincer guns to make a T-shaped sub-assembly.

All the assemblies so far produced now go to the main assembly line (*see* Fig. 66).

The main floor panel is mounted in a rotatable jig and the front suspension details, *i.e.* spacer bar, box bar, etc., are welded to the main floor longitudinals. The assembly is then transferred to a manipulator-type jig where welds inaccessible previously are completed. At this stage also the radiator brackets are arc welded on.

In a further jig the footwells are added, wheel arches and frame side sills spot welded up. Joints exposed to heavy road splash are sealed with "Supraseal" prior to welding. In all cases where a satisfactory spot weld cannot be made local arc welding is adopted. In addition, arc welding is used at various points for local reinforcement. In this jig the final operations are to add the footrest panel and dash side panels.

Out of the jig any additional spot welding required is carried out and also arc welding of corners, etc.

The bottom edge of the footwell front is bent under to form a drip mould.

At this point an A.R.O. push gun is used to series weld the main crossmember to the floor panel at four points.

Indirect or twin-spot welding has the advantage that both electrodes approach the work from the same side. It does away with complicated long throat gun arms but the twin-spot unit must deliver a higher welding current as a result of shunt losses occurring in the sheets adjacent to the electrodes. This method of series spot-welding is largely used in multispot welding machines where the welding current passes from one electrode through the upper sheet into the lower sheet and thence to the second electrode.

The A.R.O. DP.36 used (Fig. 64) is a gun of compact design with built-in welding transformer of light

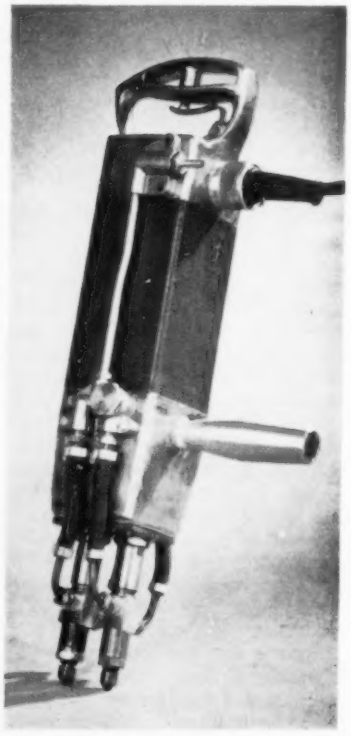


Fig. 64—This type of A.R.O twin spot welder is used on the floor panel assembly sequence

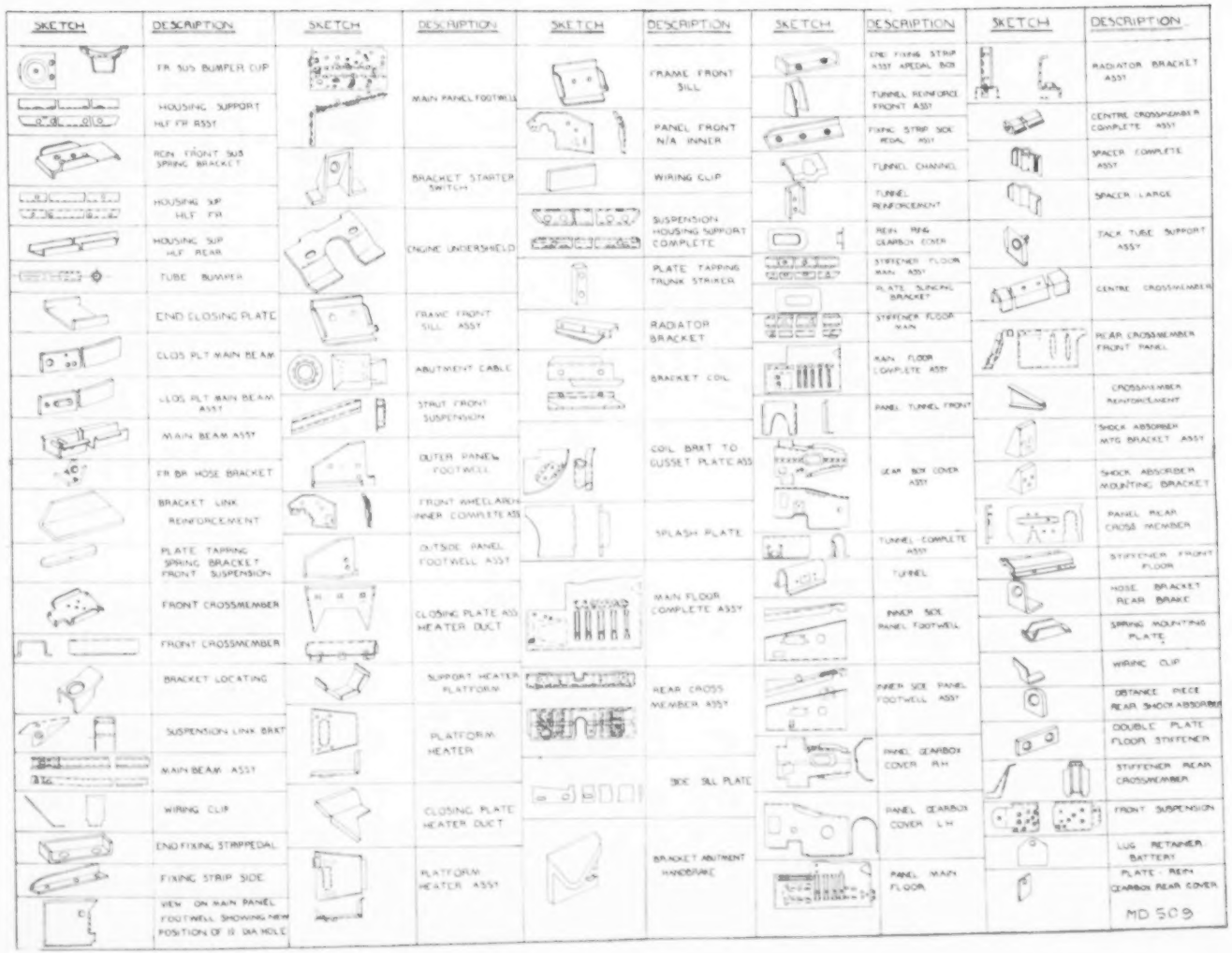


Fig. 65.—Chart identifying all component parts of "Sprite" underbody

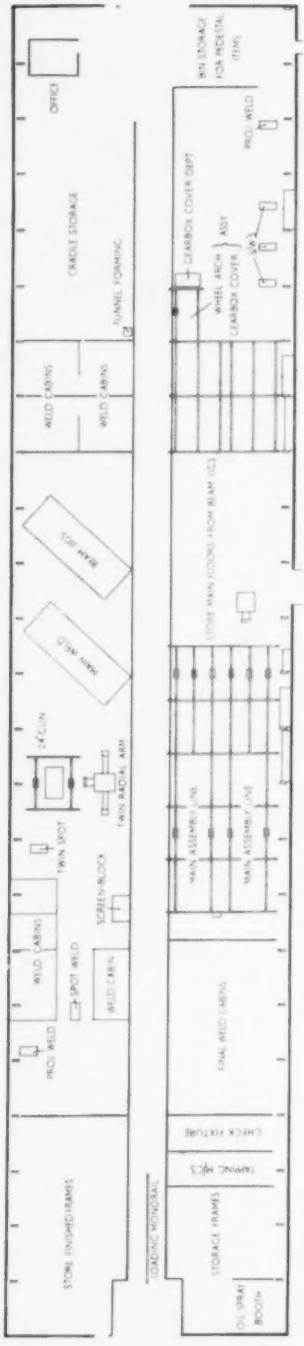


Fig. 66.—Layout of Austin-Healey "Sprite" assembly bay at the Beacon Works of John Thompson Motor Pressings Ltd. Assembly of the "Sprite" underbody involves a total of 2,066 spot welds in addition to arc welds and the attachment of nuts, etc., by projection welding. The general assembly run is from component feeder stores, to projection and pedestal welders, etc., to produce sub-assemblies which are then transferred to the main assembly-line jigs and fixtures

weight and it can tackle many assembly problems which obviates the necessity of using articulated guns which would require long or complicated arm designs. Comparatively high production rates can be achieved with the aid of this unit, especially as built-in water cooling circuitry is provided for the electrode holders, tips and transformer.

The DP.36 unit is controlled by a CD.12 control panel providing a range of weld times, steplessly adjustable between minimum and maximum limits and in addition the panel can be pre-set for thermic energy control which makes the consistent welding of scaly and slightly rusty sheet possible

Each completed frame then goes through a receiver gauge which checks all the important dimensions. Tapped holes are also checked for weld splatter, all welds are inspected, the serial number stamped on and the whole assembly then sprayed with a light oil to prevent corrosion.

COMPONENT PRODUCTION

Floor (Fig. 67 : 23)

The largest single component in the Sprite underfloor assembly is the main floor panel, which is produced from 20-s.w.g. carbody steel. Production starts with a rectangular blank which, in a 750-ton Clearing press, undergoes its first operation sequence as follows :

Draw swages and depression for feet ; pierce all holes; and clip profile at bottom of stroke.

In a further 750-ton Clearing press the second operation flanges all round and, at the bottom of the stroke makes notches (drain slits) on the centreline of the swages. The tools used for these two operations are shown in Figs. 68 and 69.

Fig. 67 (facing page).—Key to underframe components

1. *Member assembly—frame side (R/H).*
2. *Member assembly—frame side (L/H).*
3. *Plate assembly—closing—side member (R/H).*
4. *Plate assembly—closing—side member (L/H).*
5. *Plate—end closing—side member.*
6. *Bracket—bonnet locating.*
7. *Cross member—front.*
8. *Plate—closing—front cross member.*
9. *Spring bracket assembly—front suspension (R/H).*
10. *Spring bracket assembly—front suspension (L/H).*
11. *Support assembly—suspension housing.*
12. *Bracket—front—front suspension link (R/H).*
13. *Bracket—rear—front suspension link (R/H).*
14. *Bracket—front—front suspension link (L/H).*
15. *Bracket—rear—front suspension link (L/H).*
16. *Bracket assembly—radiator mounting (R/H).*
17. *Bracket assembly—radiator mounting (L/H).*
18. *Cross member assembly—centre.*
19. *Support assembly—jack tube.*
20. *Cross member assembly—rear*
21. *Bracket assembly—shock absorber mounting (L/H).*
22. *Plate—spring mounting.*
23. *Floor assembly—main.*
24. *Channel assembly—stiffening—main floor.*
25. *Tunnel assembly.*
26. *Bracket—hand brake abutment.*
27. *Cover assembly—gearbox.*
28. *Panel—tunnel front.*
29. *Panel assembly—inner side—foot well (R/H).*
30. *Panel assembly—inner side—foot well (L/H).*
31. *Panel assembly—foot well front and roof (R/H).*
32. *Panel assembly—foot well front and roof (L/H).*
33. *Panel assembly—outer—foot well (R/H).*
34. *Panel assembly—outer—foot well (L/H).*
35. *Plate—side—sill (L/H).*
36. *Strut—front suspension (R/H).*
37. *Strut—front suspension (L/H).*
38. *Support—heater platform.*
39. *Platform assembly—heater.*
40. *Wheel arch assembly—inner (front R/H).*
41. *Wheel arch assembly—inner (front L/H).*
42. *Wheel arch assembly—top (front R/H).*
43. *Wheel arch assembly—top (front L/H).*
44. *Wheel arch—outer (front R/H).*
45. *Wheel arch—outer (front L/H).*

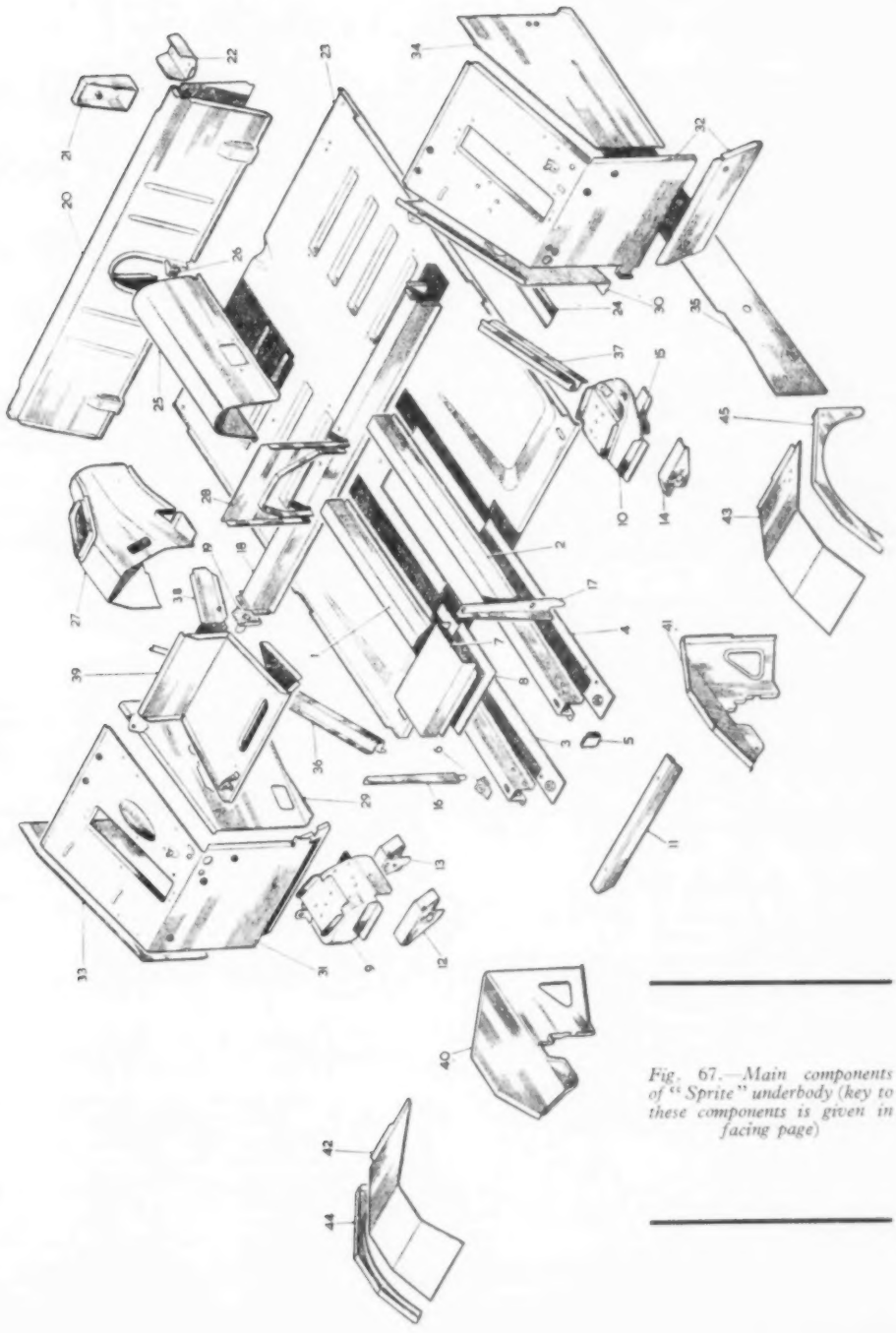


Fig. 67.—Main components of "Sprite" underbody (key to these components is given in facing page)

Front-suspension Spring-mounting Bracket

(Fig. 67 : 9 and 10)

One of the most complicated components in the Sprite frame is the front-suspension mounting bracket, which is produced in 14-s.w.g. EN2A steel (0.12 per cent carbon).

Blanks 1 ft. 1 in. × 15$\frac{3}{4}$ in. are first sheared from sheets 9 ft. 9 in. × 15$\frac{3}{8}$ in. × 14 s.w.g.

The first draw is effected in a 500-ton Taylor and Challen press, which also pierces a $\frac{1}{2}$-in. dia. hole which is used as a location for subsequent operations. Draw beads are provided on corners and the tool used (Fig. 70) incorporates Incanite components (pommel, top ring and pressure ring) flame hardened on the working surfaces.

The next operation requires a 200-ton press (of John Thompson manufacture) in which the component is clipped and a $\frac{1}{4}$-in. dia. hole pierced, as shown in Fig. 71. The clipping is done to a developed shape which, when the sides of the component are subsequently raised, gives a condition which mates up with other components, *i.e.* sidemembers.

A 500-ton Clearing press is then used for a redraw operation and for setting the flange (Fig. 72). Following operations involve piercing holes whose position is varied depending on whether the bracket is to be used left-hand or right-hand, and to effect this the steels and punches in the

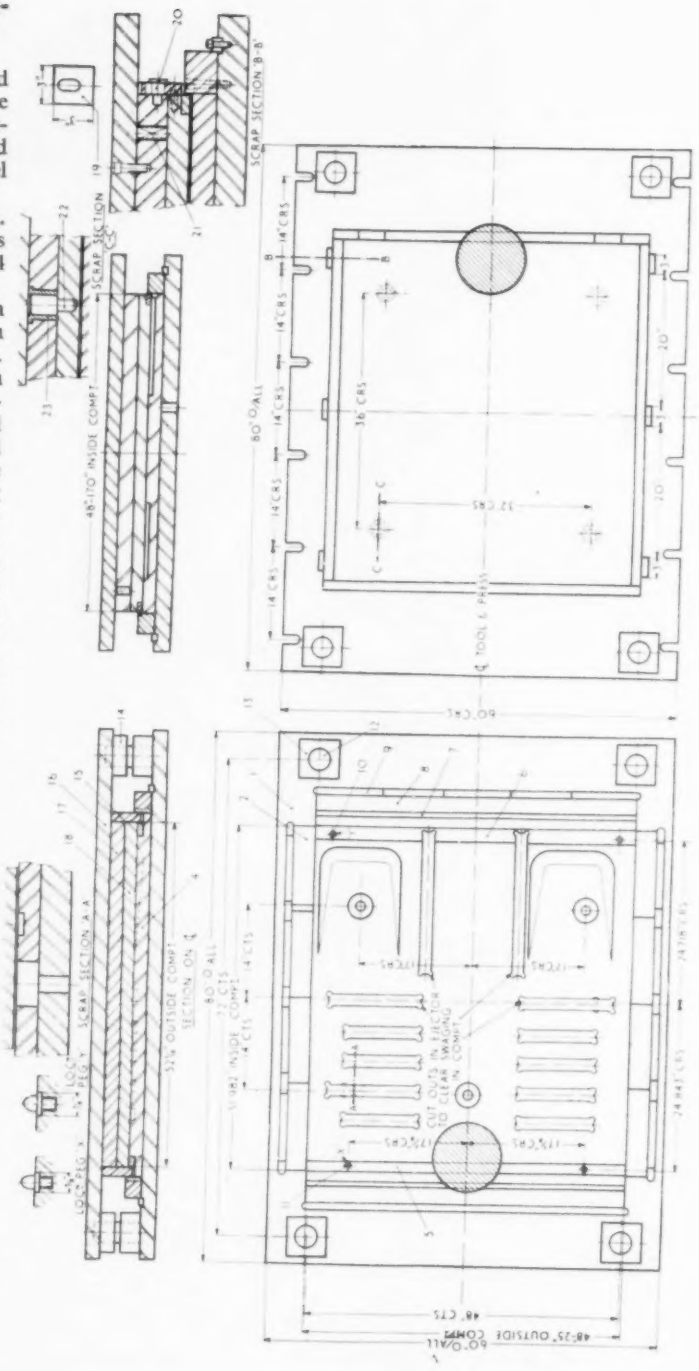


Fig. 68.—First-operation tool for main floor panel: draw swages, pierce all holes and clip profile

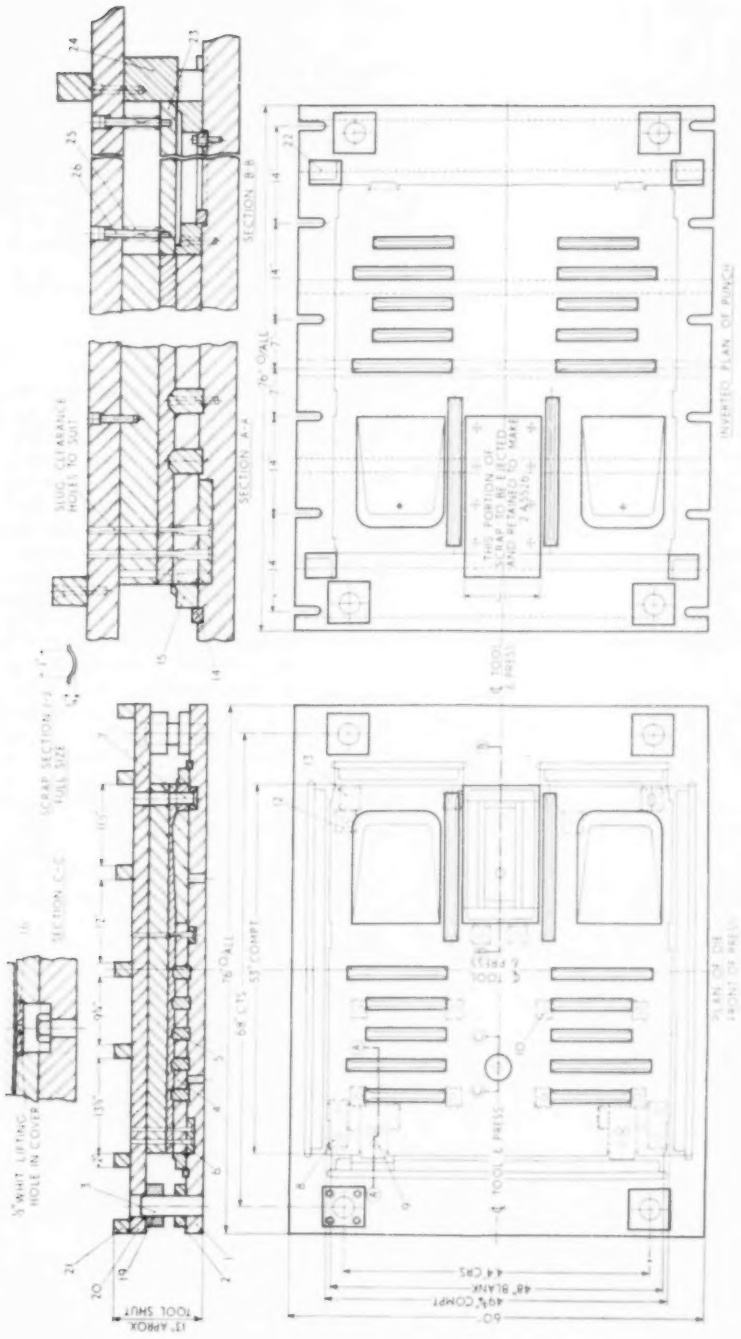


Fig. 69.—Cold press flange dies for main floor panel

tools for the next three operations are changed as required (*see* Fig. 73 atog). Using the previously pierced $\frac{1}{2}$-in. hole as a location three $\frac{7}{16}$-in. holes are pierced. Following this, and again using the $\frac{1}{2}$-in. hole as a location but in a different position, four further holes are pierced. Finally, with the component in a different position, but still using the $\frac{1}{2}$-in. hole as a location, one $\frac{9}{16}$-in. dia. hole is pierced. These three separate piercing operations are carried out using John Thompson 60-ton mechanical presses.

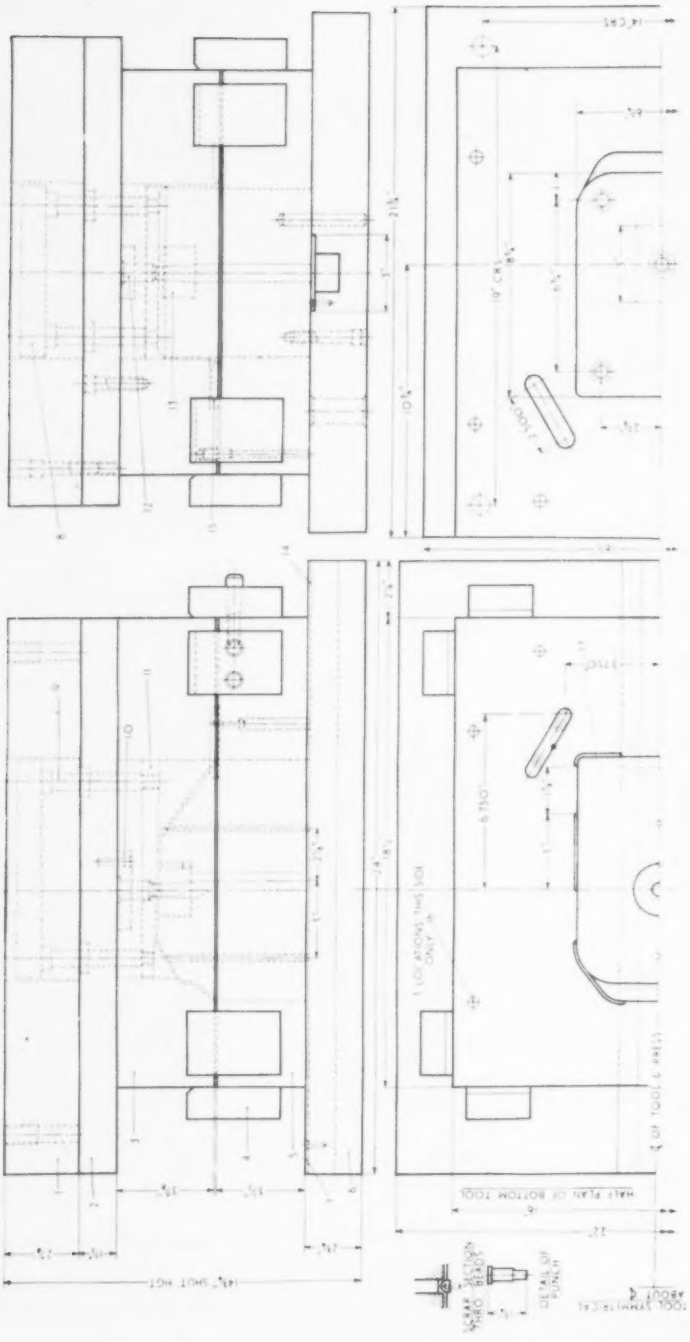
The final operation (Fig. 74) is to set the flange *i.e.*, make a joggle in the tongue. This again requires a 60-ton John Thompson press.

Rear Crossmember
(Fig. 67 : 20)

This member consists of two panels spot welded together into an inverted V-shape.

The rear panel is produced from 18-s.w.g. sheet (EN2B) sheared to 4 ft. × $1\frac{9}{16}$ in. The first operation, in a 500-ton Wilkins and Mitchell press, is to form the flutes. A similar machine is used for the two following operations, *viz:* clip and pierce and flange and raise flanges.

The front panel is in EN2B, 20 s.w.g.; the blank being 4 ft. 2 in. × 13 in.; the blanking



operation is effected in a 500-ton Wilkins and Mitchell press. A Clearing 750-ton machine is then used to plunge, form the flutes and raise the flanges. Ganged tools in a press brake then vee-bend the top edge of the panel and also pierce eight holes. These two panels are later joined by spot welding and incorporate reinforcement webs triangular in shape, which are formed in pairs on a 200-ton press using a Bowfeed.

Gearbox Cover (Fig. 67 : 27)

This component was first designed to be produced in one piece from 20-s.w.g. extra-deep-drawing quality steel but a detailed study of the economics of this operation showed that a saving in material and operating time could be effected by using two separate pressings.

The gearbox cover is thus currently pressed in two halves which are subsequently spot welded together with a strengthening collar round the gearbox aperture. One of the two half pressings is joggled down the centre line. The drawing operation makes a pair of half pressings; a 600-ton Clearing double-action press is used. Clipping, parting, piercing and flanging operations are effected in a 1,000-ton Clearing press using ganged tools.

Transmission Tunnel Front
(Fig. 67 : 28)

A sheared blank in EN2A steel, 12 $\frac{1}{16}$ in. × 13$\frac{1}{2}$ in. × 20 s.w.g., is used for this component, which is produced in two operations on 200-ton John

Fig. 70.—Front-suspension mounting bracket first-operation tool: draw and pierce

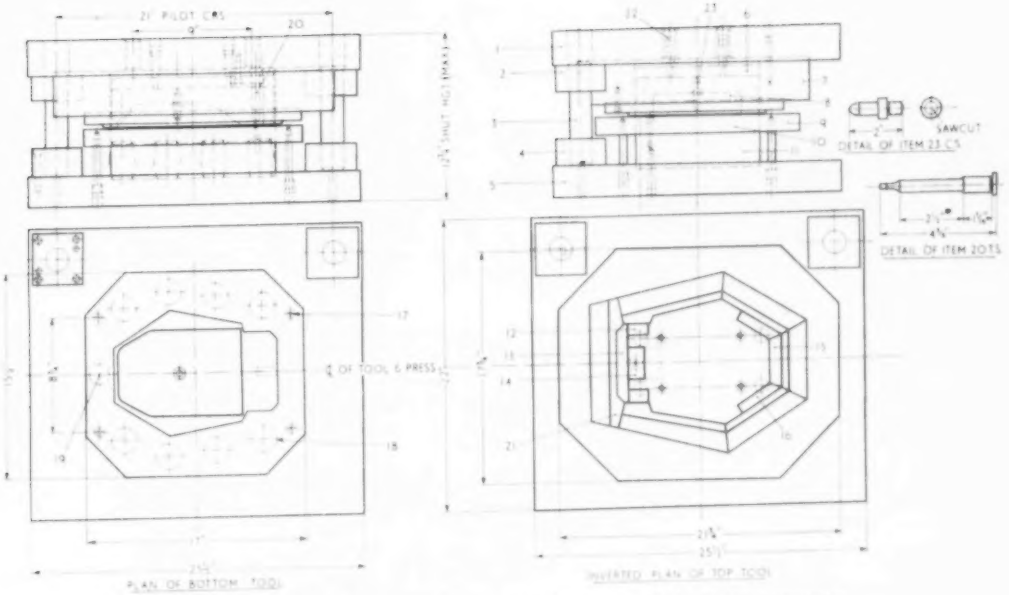
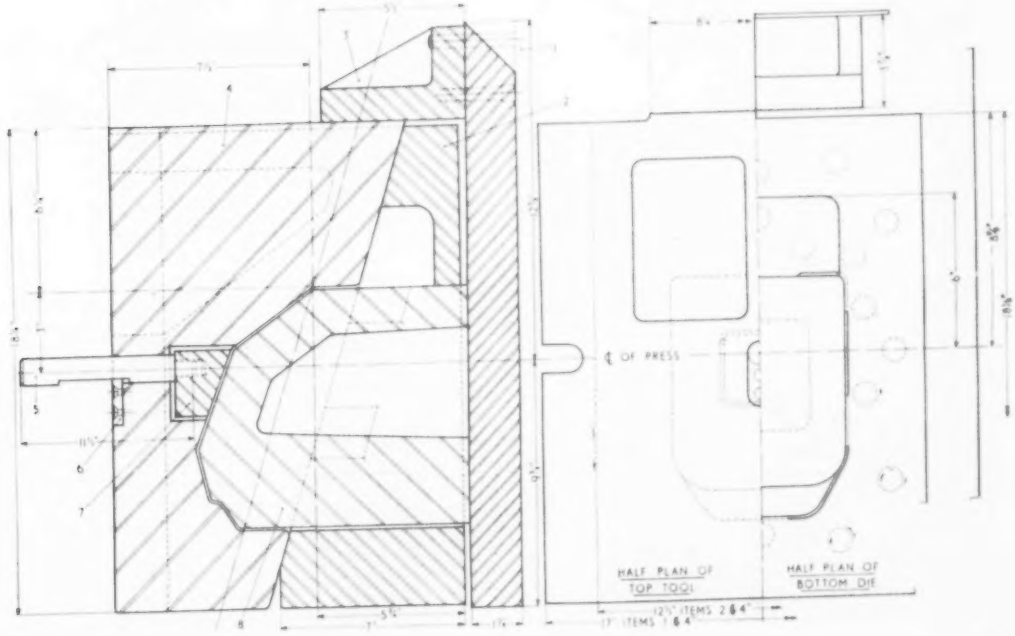


Fig. 71 (above).—Front-suspension mounting bracket: tools for clipping operation

Fig. 72 (below).—Front-suspension mounting bracket: form tools (planish (redraw), set flange)



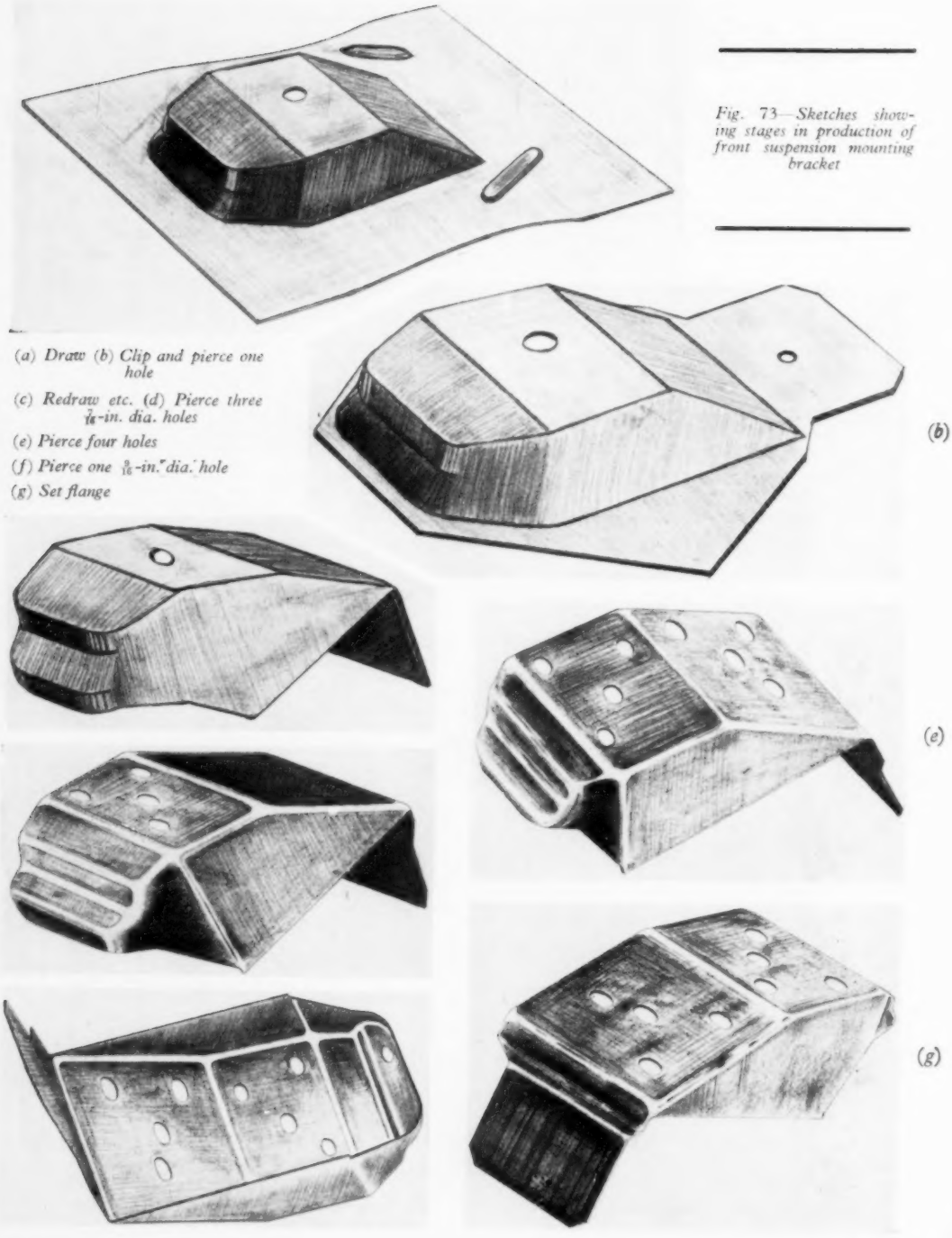


Fig. 73—Sketches showing stages in production of front suspension mounting bracket

(a) Draw (b) Clip and pierce one hole

(c) Redraw etc. (d) Pierce three $\frac{1}{16}$-in. dia. holes

(e) Pierce four holes

(f) Pierce one $\frac{5}{16}$-in. dia. hole

(g) Set flange

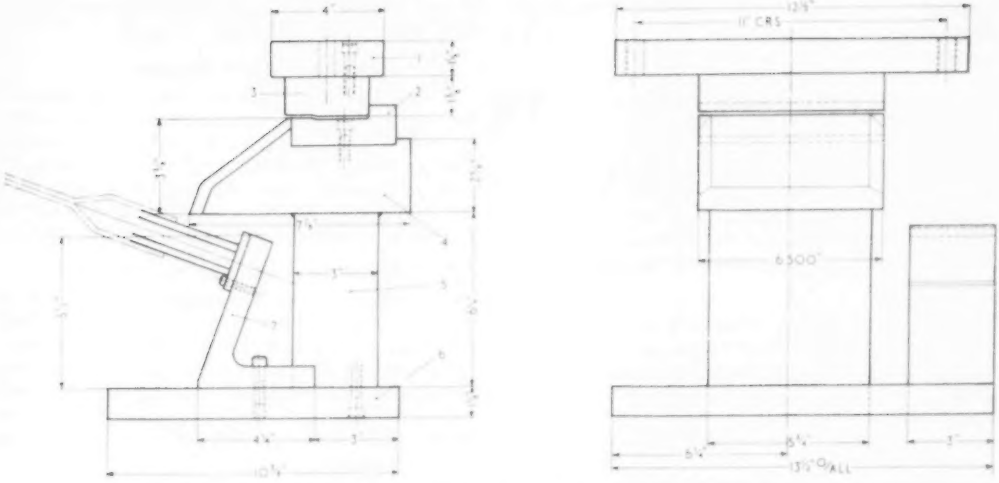


Fig. 74.—Tools for joggling the tongue on the front-suspension mounting bracket

Thompson presses. The first operation is to crop the centre piece and the ends and then to press to shape.

Transmission Tunnel (Fig. 67 : 25)

The tunnel itself is in EN2B steel, the blanks being 4 ft. 11 in. × 40$\frac{3}{4}$ in. × 20 s.w.g.; these blanks are split to 20$\frac{3}{4}$ in.

A 500-ton Wilkins and Mitchell press with a 16-in. stroke is used to pierce, notch and part. Two blows on a press brake are required to make V-bends after which the final form is effected in a simple special machine designed and built by John Thompson. The tunnel is fitted with a reinforcement bracket to which weld-nuts are attached by projection welding in a 150-kVA machine.

The special machine built by John Thompsons to form the tunnel consists of a piece of 6-in. diameter mild-steel tube, suspended horizontally above a work table (Fig. 75). The blank is first pierced and placed on the work table, which moves upwards toward the tube. At the same time two arms pivoted below the table wrap the blank round the tube (Fig. 76). The diameter of the tube and position of the arm pivots is such that the degree of overbend given to the blank ensures that the correct bend radius is obtained when the arms are released.

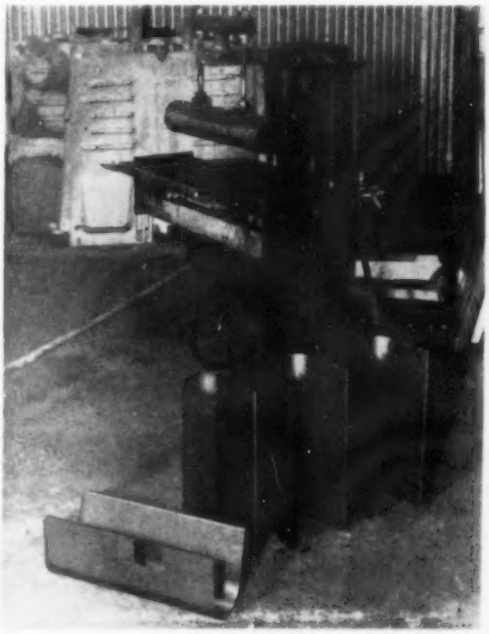
Side Sill Plates (R.H. and L.H.). (Fig. 67 : 35)

In EN2B steel, these components are produced from sheared blanks 4 ft. 4$\frac{3}{4}$ in. × 6$\frac{3}{8}$ in. × 0.0625 in. In a 750-ton Bliss press the first operations are blank and pierce. A 60-ton John Thompson press is then used to raise flanges.

Main Beam (R.H. and L.H.). (Fig. 67 : 2)

EN2B sheet 7 ft. 11$\frac{1}{2}$ in. × 33$\frac{1}{2}$ in. × 18 s.w.g. is sheared to 95 in. long × 6$\frac{5}{8}$ in. wide. A press brake is used to crop ends, pierce and part. The main

Fig. 75.—General view of special machine for forming transmission tunnel



form operation is effected in a 500-ton Wilkins and Mitchell press.

Centre Crossmember (Fig. 67 : 18)

The blanks for this member, produced in EN2B steel are 4 ft. $1\frac{3}{8}$ in. $\times 8\frac{1}{2}$ in. $\times$ 18 s.w.g. A 500-ton Wilkins and Mitchell press crops the ends, parts and pierces holes, following which, in ganged tools in a press brake, the flanges are formed. The rail section is formed in a further 500-ton Wilkins and Mitchell press. Spacers are spotwelded to the member and jack tube supports attached by arc welding.

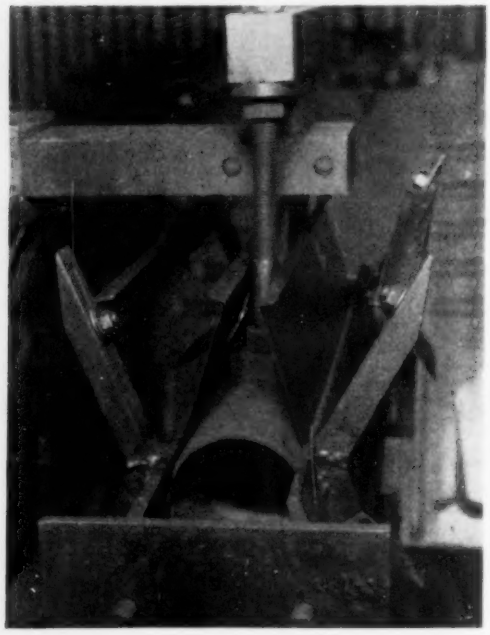
Inner Side Panel—Footwell (Fig. 67 : 30)

These panels, in EN2A steel, are blanked and pierced in pairs on a 500-ton Wilkins and Mitchell press ; the same type of machine is also used to raise flanges in a subsequent operation. A pair of panels is produced from a blank 1 ft. $5\frac{1}{8}$ in. $\times$ $33\frac{3}{8}$ in. $\times$ 20 s.w.g.

Suspension Link Brackets (Fig. 67 : 12, 13, 14, 15)

A blank in EN2D/1 steel, 7 ft. 2 in. $\times$ 34 in. $\times$ 14 s.w.g. produces 24 pairs of these brackets. The blank is sheared into widths of $8\frac{1}{2}$ in. The first operations being blank and pierce in a 200-ton John Thompson press. A pair of brackets is formed at once in a 200-ton John Thompson press fitted with a transfer device.

Fig. 76.—Close-up of special machine for forming transmission tunnel



Front-suspension Bumper Cup

A blank 8 in. $\times$ $8\frac{1}{2}$ in. $\times$ 16 s.w.g. is used for this component, which is first blanked and drawn on a 180-ton Taylor and Challen press ; a similar machine is used for a redrawing operation. A third draw produces the taper, the fourth operation being clip and pierce 3 holes. The final operation is to set and raise flanges in a 75-ton Butterley press.

Front Crossmember (Fig. 67 : 7)

Of top-hat section, this member, which is later fitted with a closing plate, is produced from 18-s.w.g. EN2A steel 12 in. wide. The main operations are effected in a 75-ton Butterley press equipped with a Bowfeed, these operations being crop cutouts, pierce, and part off. The second operation, V-bend, is effected in a press brake in four blows.

Platform for Heater (Fig. 67 : 39)

Produced in three stages from EN2A steel, the starting blanks are $18\frac{1}{2}$ in. $\times$ $32\frac{1}{2}$ in. $\times$ 20 s.w.g. The first two stages are done on 500-ton Wilkins and Mitchell presses and the third on a press brake. The operations are blank and pierce, plunge and raise flanges, and bend.

Support for Heater Platform (Fig. 67 : 38)

A sheared rectangular starting sheet 1 ft. $8\frac{5}{8}$ in. $\times$ $3\frac{3}{8}$ in. $\times$ 20 s.w.g. in EN2A steel is used. A 200-ton John Thompson press is used to notch the cut-outs and set the ends after which the two end bends are made in a press brake. A 60-ton press is used to bend the centre.

Front Wheel-arch Inners (Fig. 67 : 40, 41)

EN2A steel is sheared to 1 ft. $11\frac{1}{2}$ in. wide $\times$ 29 in., the thickness being 20 s.w.g. To avoid a double run and to save material, the components are blanked and pierced in pairs in a 500-ton Wilkins and Mitchell press. After prebending in pairs on a press brake, a further 500-ton press is used to plunge and raise flanges, also two at a time. The final operation is to pierce a triangular hole using a 30-ton John Thompson press.

* * *

Although the above descriptions of the production of a few of the Sprite components are necessarily brief, they indicate the complexity of the production of a body of this type, particularly if reference is made to Fig. 65 drawings of the component parts and Fig. 67 an exploded view of a complete assembly.

Details of the assembly of the Austin-Healey "Sprite" underbody, including the special British Federal welding set-up, will be given in the next issue.

The Welding of ALUMINIZED STEEL SHEET

By T. M. MOLOSSI, B.A.* and J. H. NICHOLLS, A.R.I.C.*

FOR the guidance of fabricators who have, so far, had no experience of welding aluminized steel sheet, the authors give below data and information obtained from trials and experimental work carried out by the British Oxygen Company Ltd.[1] and Sciaky Electric Welding Machines Ltd.[2]

Aluminized steel will be employed either because of its outstanding corrosion resistance, or because of its ability to withstand high service temperatures for considerable lengths of time. These properties are a consequence of the aluminium coating, and since in welding some disturbance of this protective layer is inevitable, design and production methods may have to be slightly modified to keep this damage to a minimum. However, with "ALUDIP"[3], the area affected is much smaller than with zinc, lead, or tin coated sheets because of the much higher melting point of aluminium. Naturally, the heat and corrosion resistance of the weld is not as high as in the original sheet but tests have established that, provided undue heating is avoided, there is no substantial decrease in the desirable properties of the material.

Welding methods can be conveniently considered under two sections: resistance and fusion methods. Resistance welding is more widely employed as it lends itself particularly well to mass-production techniques. It is well known that aluminium has a much higher thermal and electrical conductivity than steel, and in consequence more electrical power must be dissipated to produce a resistance weld with "ALUDIP" than with mild steel. While AID and ARB specifications relating to the resistance welding of aluminium sheet demand the most scrupulous surface preparation, this is not advisable for normal routine production requirements with "ALUDIP" unless the surfaces have become heavily soiled in transit or storage. The presence of the normal, protective oxide skin (to which aluminium owes its excellent corrosion resistance) facilitates the build-up of heat at the metal interface, and permits the use of lower power machines than would otherwise be required.

* Coated Metals Ltd.

(1) Spot Welding

In the spot welding of "ALUDIP", it has been found that chrome-copper electrodes were more suitable than those made from hard-drawn copper, which does not appear to retain its shape as well. Water cooling is essential to minimize aluminium pick-up by the electrode tip.

In form, the electrode should be a truncated cone having an internal angle of 120 deg. Conditions suitable for various thicknesses of material are given in Table I, but it must be emphasized that these refer to general conditions and slight variations can be expected depending on the circumstances. None the less, these settings will be found satisfactory for general use.

TABLE I

	Tip diameter	Electrode force	Welding current	Welding time
20 gauge	$\frac{3}{16}$ in.	400 lb.	9,000 amp.	12 cycles
18 gauge	$\frac{7}{32}$ in.	550 lb.	11,000 amp.	15 cycles
16 gauge	$\frac{1}{4}$ in.	650 lb.	12,000 amp.	18 cycles

With 16-gauge material, a shear strength of 1,300 lb. per spot weld was typical.

(2) Projection Welding

Projection welding is related to spot welding and has several advantages which make it a valuable production method. The essential characteristic of the process is that the material is indented prior to welding : in this way the material is made to act as a false electrode tip. Because the area of current input is so much greater than the area of fusion, damage to the external surfaces is kept to an absolute minimum. Typical values of settings used to produce three simultaneous projection welds are given in Table II.

TABLE II

Gauge	Electrode force	Welding time	Secondary current (Short circuit)
16 + 16	1,500 lb.	30 cycles	24,000 amp.
18 + 18	1,000 lb.	20 cycles	18,000 amp.

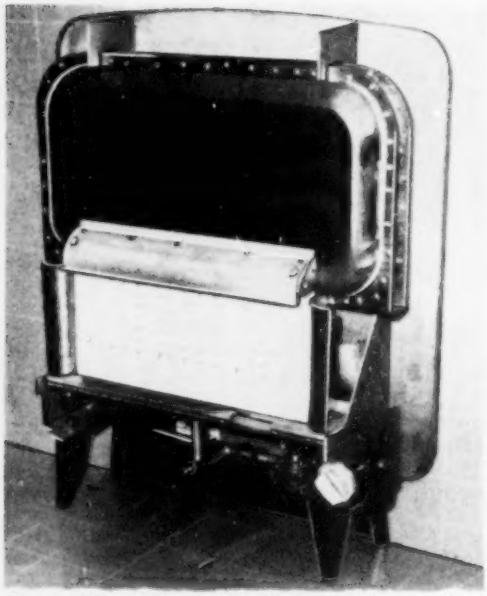


Fig. 1.—The convector unit in this Bratt Colbran gas fire is made from dished "ALUDIP" panels spot-welded together (Courtesy of Bratt Colbran Ltd.)

(3) Seam Welding, and Stitch Welding

Seam welding is very easily carried out with aluminized steel sheet. The localized heating encourages the formation of an alloy phase which effectively seals the weld to give a gas- and liquid-tight joint. This is shown in Fig. 3, a photomicrograph of a section through such a weld.

It is interesting to note that two ten-inch squares of 16-g. "ALUDIP" have been seam welded in the form of a pillow and inflated to a pressure of ninety pounds per square inch without air escaping from the joints.

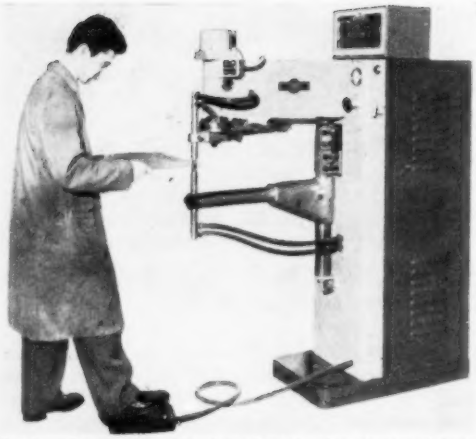
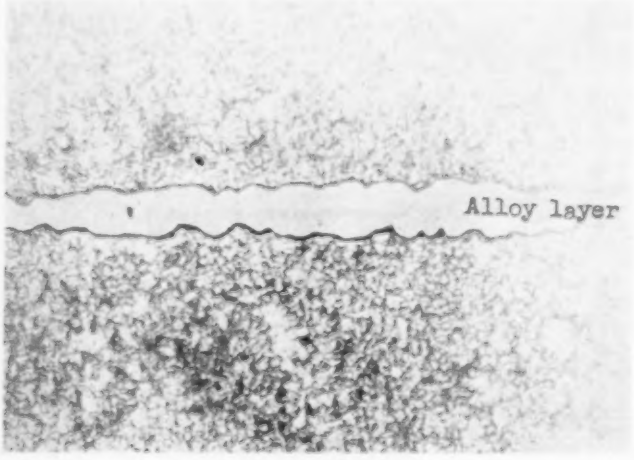


Fig. 2.—Spotwelding aluminized steel using truncated cone electrodes with included angle of 120 deg. (Courtesy of Sciaky Electric Welding Machines Ltd.)

In Table III lap seam welding data obtained with a Sciaky universal seam-welding machine, Type R.A.M.U. 75 are given.

The electrode wheels were manufactured from Sciaky Blue Spot chrome-copper alloy, and machined with an internal tread angle of 120 deg. Fairly high pressures and internal water cooling result in very small coating pick-up; in fact, pick-up is only evident during the first few revolutions of a wheel with a freshly machined tread, and there seems to be no need for alteration of the setting thereafter. Some degree of self dressing is provided by a knurled drive.

Unless a complete steel steel weld is required,



Photomicrograph of section through seam weld showing alloy phase

TABLE III

	Roller tread width	Electrode force	Timing		Duty cycle	Welding current	Speed, in. per min.
			On	Off			
20 gauge	$\frac{3}{16}$ in.	850 lb.	2	2	50 per cent	12,000 amp.	84
18 gauge	$\frac{7}{32}$ in.	1,100 lb.	2	2	50 per cent	15,000 amp.	60
16 gauge	$\frac{1}{4}$ in.	1,340 lb.	3	2	60 per cent	18,000 amp.	48

which requires a higher energy input, the corrosion and heat resistance of seam welds are good.

Stitch welding is governed by much the same considerations as seam welding, from which it differs in that it is a manually controlled operation, is more variable, and can be carried out in circumstances where it is physically impossible to introduce an electrode wheel.

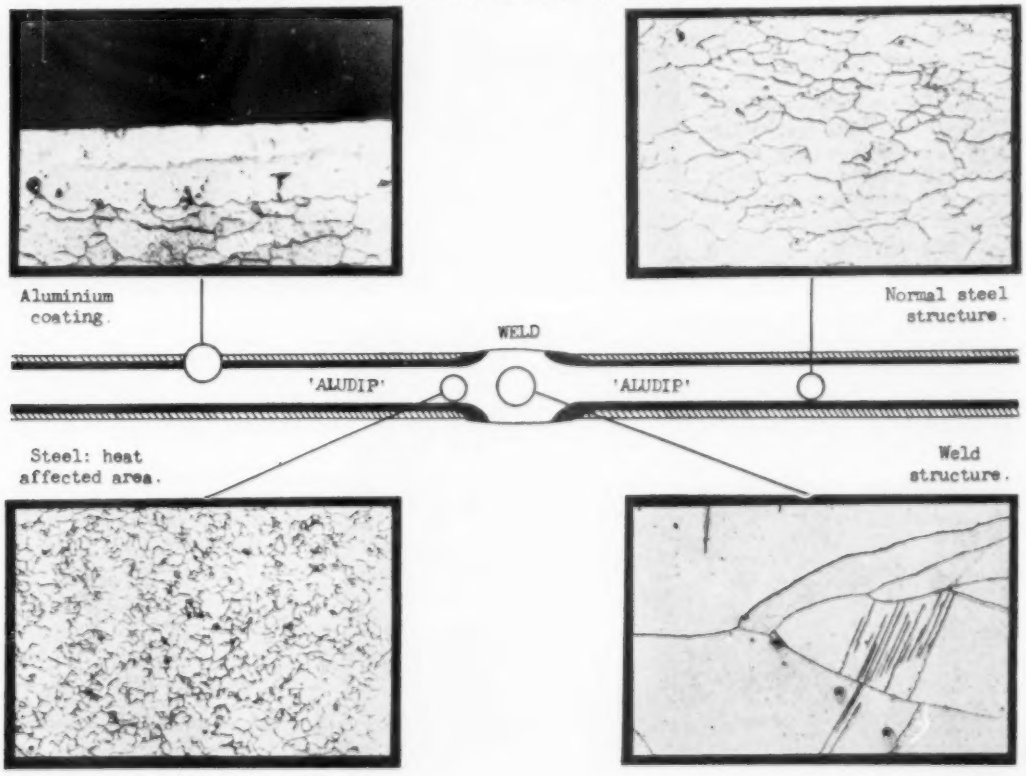
(4) Resistance Butt Welding

Two types of resistance butt welding are in common use : slow butt welding for sheets having a thickness less than 0.015 inches, and flash-butt welding for heavier materials. Both types require a well-prepared edge for optimum results, but the more violent nature of the operation leads to local destruction of the aluminium coating. Butt welding is to be recommended in applications where mechanical strength is the main requirement ; for subsequent corrosion resistance the weld area should be covered with an aluminium paint based on a good-quality leafing aluminium powder. This recommendation should be followed in all cases where a high degree of corrosion resistance is sought.

(5) Brazing

Brazing can be carried out by arc or gas methods, using either silicon aluminium or a copper based alloy rod. Neither gives a particularly strong joint, but in certain applications they may be adequate. If

Fig. 4.—Section through butt-welded "ALUDIP". At the extreme ends of the diagram the coating and steel are normal. Entering the heat-affected zone the grain-size of the steel is reduced and the pure aluminium outer layer of the coating is converted wholly to alloy. In the weld itself some "twinning" due to retained austenite can be seen



the silicon/aluminium rod is used, it should be borne in mind that the strength of the joint decreases rapidly as the service temperature rises : 200°C. should not be exceeded. Using a copper-based alloy rod, the user should bear in mind the possibilities of contact corrosion : aluminium and copper differ widely in potential, and in the presence of an electrolyte first the adjacent aluminium coating and then the steel base would be rapidly attacked. Fluxes, which contain fluorides and or chlorides, are potentially dangerous if care is not taken to wash off all the residues subsequently.

(6) Argon-arc Fusion Welding

This is a simple and versatile technique of wide industrial application. In butt welding, local destruction of the aluminium coating is inevitable, but owing to the solution of aluminium in the weld it has some resistance to corrosion. This dissolved aluminium has little physical effect on the strength of the weld: indeed, mild-steel filler rods often contain additions of aluminium to produce desirable effects. Fig. 4 shows the changes in the structure of the metal which take place across an argon-arc butt weld.

Usually some cracking takes place in an argon-arc butt weld unless a filler rod is used. The most suitable type appears to be the 18 per cent chromium, 8 per cent nickel, and 1 per cent niobium alloy complying with the requirements of British Standard Specification 2901.

During the welding operation there is some dilution of the stainless-steel filler and some slight rusting may occur at a later date. It should be noted that this is extremely mild and superficial and does not appear to progress beyond a mild coloration. At the present time considerable experimental work is being carried out to eliminate this characteristic ; the use of nickel-chrome wire shows much promise in this application.

It might be expected that the use of a stainless-steel filler wire would greatly increase the cost of the welding operation, but this is not so. It is true that the stainless-steel wire costs about four times as much as a mild-steel wire, but because the material cost is small compared with plant depreciation

(*Continued in page* 146)

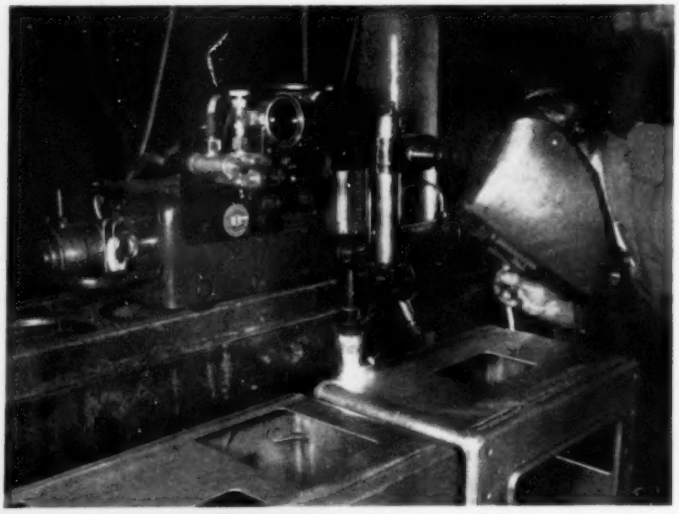


Fig. 5 (above).—Argon-arc welding of tanks

(Courtesy of the British Oxygen Co. Ltd.)

Fig. 6 (left).—Argon-arc spot welding

(Courtesy of British Oxygen Gases Ltd.)

TOOLING for Cold Extrusion

By R. A. P. MORGAN, O.B.E., M.I.Mech.E*

(A paper presented at the Special Conference on "Cold Extrusion of Steel" organized by the Institute of Sheet Metal Engineering, at the City Hall, Sheffield, November 21 to 23, 1960.)

THE cold extrusion of steel is a process where the tools are stressed to the top limit of their physical properties, having to withstand repeated stressing up to 120 tons per sq. in.

In order to achieve maximum tool life under these arduous conditions every effort must be made to reduce the complexity of stress, and keep, if at all possible, the tools under compression. The weakest part of the tooling for this process is, of course, the punch, the design of which is mostly governed by the shape of the component to be produced. The die, as will be seen later, can be designed so that the stress pattern can be spread by the use of reinforcing rings, and therefore, does not present the same problem. It should, therefore, be borne in mind, that any inaccuracy in the tools, tool holders, pressure pad, press adaptors, or even the presses themselves will give rise to eccentric loading and induce bending stresses into the punch. This will seriously shorten its working life.

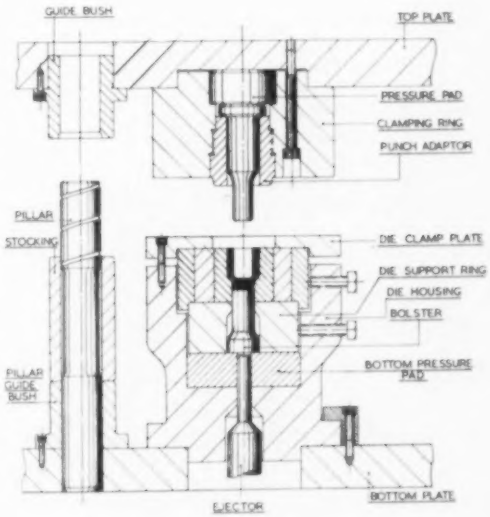
No matter how well a press may be made, running clearances between the working parts is essential and, therefore, a press under load must have some inaccuracy as to alignment. In order to eliminate this as far as possible, sub-press tools are considered essential, such tools having an added advantage insofar that they can be assembled before fitting to the press and once assembled can be stored for future use. In this way more than one operation can be carried out per press with a minimum of down time. Before quoting actual tolerance from the various parts of extrusion tooling it will probably be as well to define what is thought to be the four basic methods of extrusion. It is, of course, possible to produce components using a combination of these methods.

1. Backward extrusion is used for forming a hollow body from a solid billet either cropped, sawn, or parted off from bar stock. The billet diameter is the same as the outside diameter of the finished extrusion and the metal movement is in the opposite direction to the applied load. In other words the metal flows back over the punch. A typical tool set up for such an operation is shown in Fig. 1.

2. Forward extrusion of a solid bar as shown in Fig. 2. Here again a solid billet is used but in this case there is a reduction in diameter from billet to component and the metal moves forward, that is, in the same direction as the applied load.

3. Forward extrusion of a hollow body as in Fig. 3. This method is used for extruding a thick-ended cylinder whose length-to-diameter ratio is too high to be produced by backward extrusion. This method is commonly called a Hooker type of extrusion, after the American patentee. It is essential to start with a cup (normally

Fig. 1.—Typical tool set for backward extrusion



* R.O.F., Birtley.

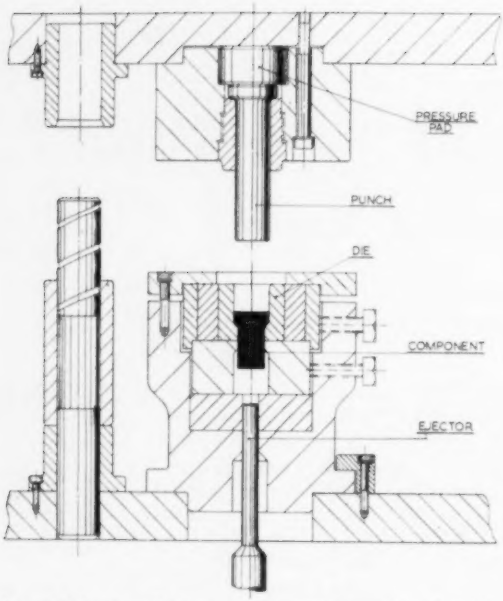
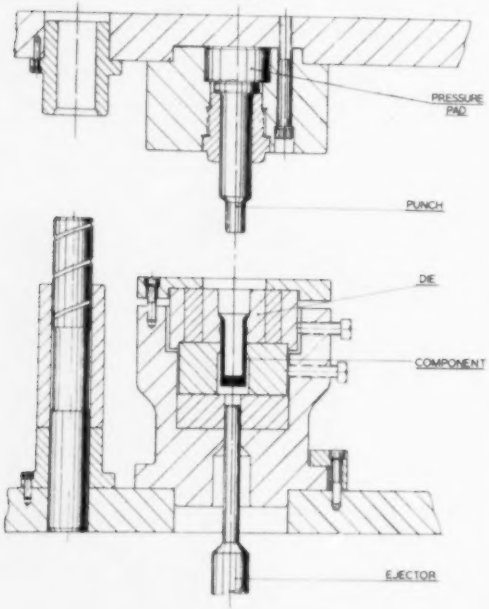
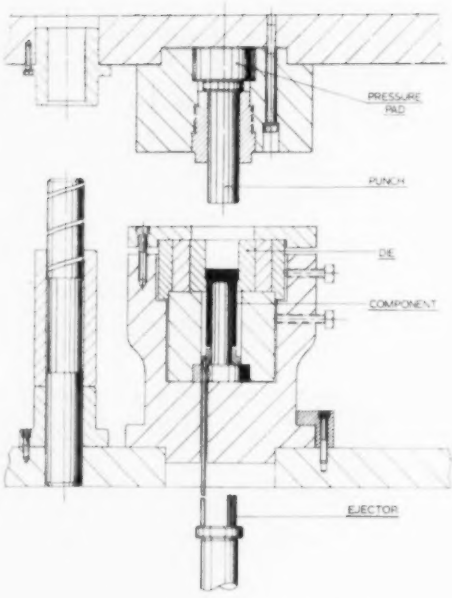


Fig. 2 (above).—Tool set for forward extrusion of solid components

Fig. 3 (below)—Tool set for forward extrusion of tubular body



FORWARD EXTRUSION - HOLLOW BODY



FORWARD EXTRUSION OF HOLLOW BODY FROM SOLID BAR

Fig. 4 (above).—Tool set for forward extrusion of hollow body from solid billet

produced by backward extrusion) and again the metal movement is forward.

4. Forward extrusion of a hollow body from a solid billet, Fig. 4. This method is classed as a forward extrusion, although the metal does flow back over the bottom punch or bolster, there is, however, relative movement between the unextruded part of the billet and the die walls in the direction of the applied load.

The extrusion load for a backward extrusion as in Fig. 1 is normally some 20 per cent higher than for the other methods, hence, in this type of tooling arrangement, the max. stresses can be expected, and the highest accuracy called for, although in practice, tools and adaptors are made to the same tolerance for all types of extrusion.

Fig. 5 shows an exploded view of the punch and adaptors from Fig. 1 with the degree of accuracy expected, while Fig. 6 gives similar details of the die.

Particular attention must be paid to the pressure pad in design, heat treatment and accuracy. They should be of ample thickness to prevent deflection under load, they must be flat and be hard enough to resist indentation. Table I gives typical material and hardness values for the various tooling items. The actual punch and die are omitted because they are dealt with in detail later.

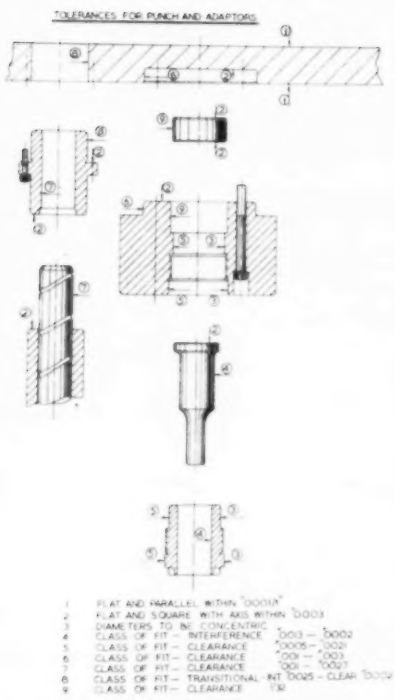
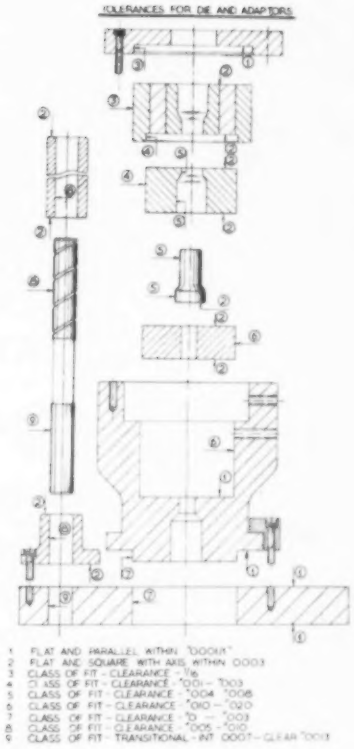

TOLERANCES FOR PUNCH AND ADAPTORS
1 FLAT AND PARALLEL WITHIN .0001"
2 FLAT AND SQUARE WITH AXIS WITHIN .0003
3 DIAMETERS TO BE CONCENTRIC
4 CLASS OF FIT – INTERFERENCE .0013 – .0002
5 CLASS OF FIT – CLEARANCE .0005 – .0021
6 CLASS OF FIT – CLEARANCE .0001 – .0013
7 CLASS OF FIT – CLEARANCE .001 – .0027
8 CLASS OF FIT – TRANSITIONAL INT .0025 – CLEAR .0002
9 CLASS OF FIT – CLEARANCE .132

Fig. 5 (left).—Tolerances for punch assembly

Fig. 6 (right).—Tolerances for die assembly

Table I (below, left)—Materials and hardness values of tooling items.


TOLERANCES FOR DIE AND ADAPTORS
1 FLAT AND PARALLEL WITHIN .0001"
2 FLAT AND SQUARE WITH AXIS WITHIN .0003
3 CLASS OF FIT – CLEARANCE – "16
4 CLASS OF FIT – CLEARANCE – .001 – .003
5 CLASS OF FIT – CLEARANCE – .004 – .006
6 CLASS OF FIT – CLEARANCE – .010 – .020
7 CLASS OF FIT – CLEARANCE – .0 – .003
8 CLASS OF FIT – CLEARANCE – .005 – .010
9 CLASS OF FIT – TRANSITIONAL – INT .0007 – CLEAR .0013

MATERIALS FOR PRESSURE PADS AND ADAPTORS FOR THE BACKWARD EXTRUSION SUB PRESS TOOL

PUNCH ASSEMBLY

ADAPTOR	MATERIAL	HARDNESS Rc
PRESSURE PAD	2%C.12%Cr STEEL	61
CLAMPING RING	8/9% CARBON STEEL	62
PUNCH ADAPTOR	8/9% CARBON STEEL	62
TOP PLATE	MILD STEEL	
GUIDE BUSH	8/9% CARBON STEEL	62

DIE ASSEMBLY

ADAPTOR	MATERIAL	HARDNESS Rc
DIE SUPPORT RING	8/9% CARBON STEEL	62
BOTTOM PRESSURE PAD	2%C.12%Cr STEEL	61
DIE HOUSING	MILD STEEL	
DIE CLAMP PLATE	MILD STEEL	
BOTTOM PLATE	MILD STEEL	
PILLAR	8/9% CARBON STEEL	62
STOCKING	MEEHANITE	
PILLAR GUIDE BUSH	8/9% CARBON STEEL	62
BOLSTER	6%. 2%Si.75%Mo. STEEL	61
EJECTOR	En 25 STEEL	± 51

EXTRUSION DIE DESIGN

Introduction

As previously stated the extrusion load on the punch is generally of the order of 120 tons per sq. in This pressure which is exerted by the punch, can be considered to be a hydrostatic pressure in the die and therefore a radial compressive force of 120 tons per sq. in. acts on the bore of the die causing it to expand. This radial compressive force causes a tensile hoop stress in the die which in a die where the outside diameter is 4.1 times the bore diameter is 135.39 lb. per sq. in. at the die bore and 15.18 tons per sq. in. at the outside diameter. A tensile hoop stress of 135.39 lb. per sq. in. is too great for the die steel to withstand unaided and to offset this, therefore, it is current practice to build up a die from a number of rings. Thus the die would consist of a die insert and one, two or more shrink rings. The shrink rings are so designed as to have interference between mating diameters of adjacent rings and also between the inner shrink ring and the die insert. This interference imposes a compressive hoop stress on the inner shrink rings and also the die insert.

The compressive hoop stress imposed by all the shrink rings has an accumulative effect when

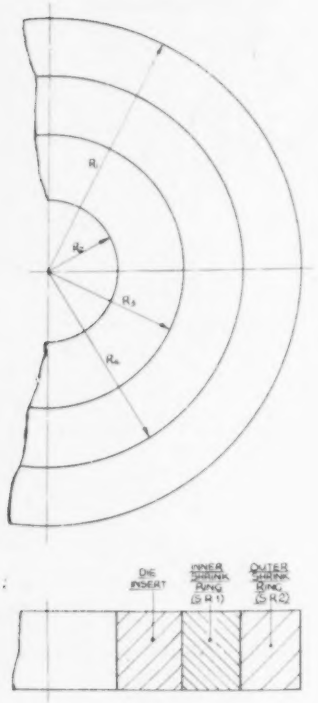


Fig. 7 (left).— Optimum die design

Fig. 8 (right).— Tempering curves of En 25 steel

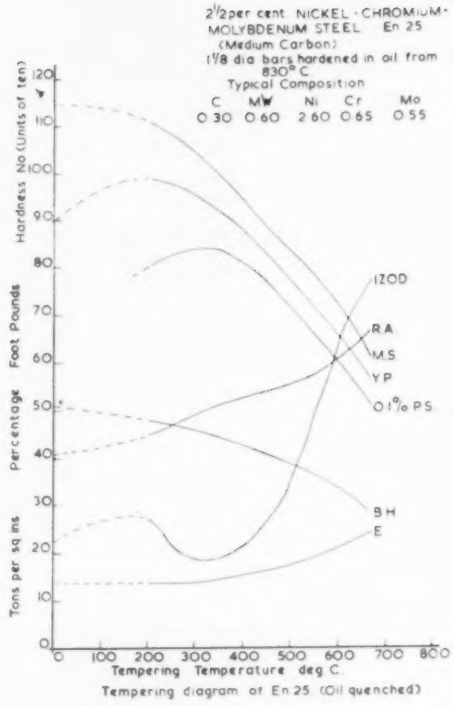
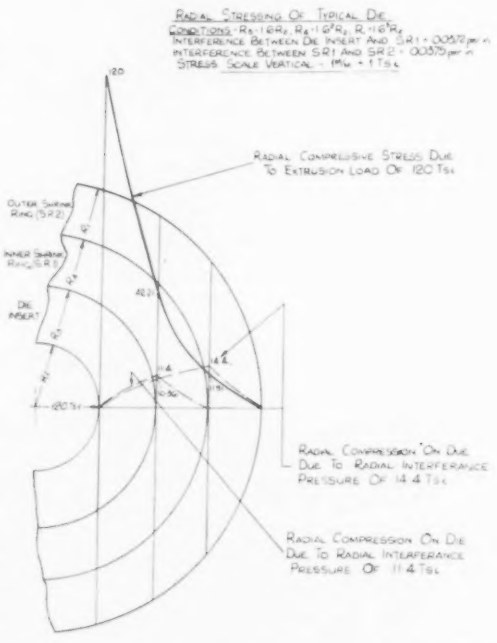


Fig. 9 (below).— Radial-stress condition of composite die


RADIAL STRESSING OF TYPICAL DIE
CONDITIONS: R3 = 1·6R2, R4 = 1·6²R2, R1 = 1·6³R2
INTERFERENCE BETWEEN DIE INSERT AND SR1 = 0·0072 per in
INTERFERENCE BETWEEN SR1 AND SR2 = 0·0079 per in
STRESS SCALE VERTICAL = 1in = 1 Tsi
RADIAL COMPRESSIVE STRESS DUE TO EXTRUSION LOAD OF 120 Tsi
OUTER SHRINK RING (SR2)
INNER SHRINK RING (SR1)
DIE INSERT
RADIAL COMPRESSION ON DIE DUE TO RADIAL INTERFERANCE PRESSURE OF 14·4 Tsi
RADIAL COMPRESSION ON DIE DUE TO RADIAL INTERFERANCE PRESSURE OF 11·4 Tsi

considered as acting at the bore of the die insert and the tensile hoop stress on the bore of the die caused by the work load can, therefore, be substantially reduced. This insert can be made of either tungsten carbide or tool steel. The following remarks apply to a tool-steel insert.

It has also been ascertained that for normal cold extrusion of steel the best design of die, as shown in Fig. 7, is a combination of a die insert and two shrink rings and the best ratio of the radius of the outside diameter of each of the rings in the composite die with the radius "R_2" of the die bore is as follows :

Radius R_3 of die insert $= 1.6\ R_2$

Radius R_4 of inner shrink ring $= 1.6^2R_2 = 2.56R_2$

Radius R_1 of outer shrink ring $= 1.6^3R_2 = 4.1R_2$

The degree of interference fit between all mating rings will depend upon the steel which is used for the shrink rings. EN.25 steel has been generally used which will give a strength of up to 80 tons per sq. in. tensile when tempered at 450° C. (Fig. 8). In the calculations which follow the strength of the shrink rings has been set at 60 tons per sq. in. which gives a 20 tons per sq. in. margin for variation in the theoretical yield strength of the steel and also

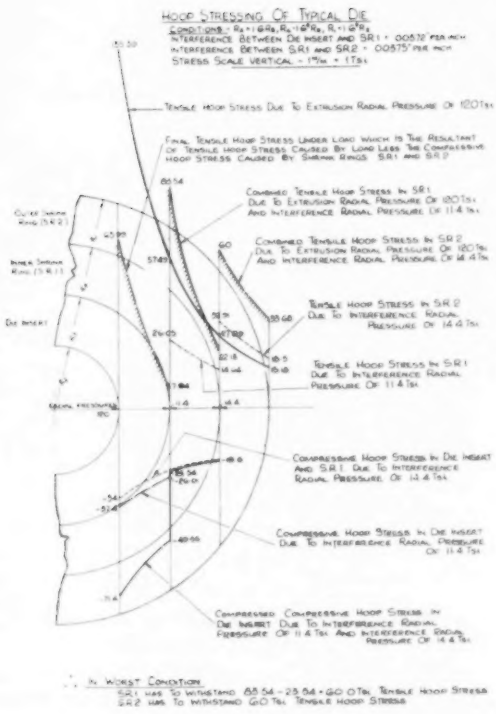

HOOP STRESSING OF TYPICAL DIE
TENSILE HOOP STRESS DUE TO EXTRUSION RADIAL PRESSURE OF 120 TSI
COMBINED TENSILE HOOP STRESS IN SR1 DUE TO EXTRUSION RADIAL PRESSURE OF 120 TSI AND INTERFERENCE RADIAL PRESSURE OF 11.4 TSI
COMBINED TENSILE HOOP STRESS IN SR2 DUE TO EXTRUSION RADIAL PRESSURE OF 120 TSI AND INTERFERENCE RADIAL PRESSURE OF 14.4 TSI
TENSILE HOOP STRESS IN SR2 DUE TO INTERFERENCE RADIAL PRESSURE OF 14.4 TSI
TENSILE HOOP STRESS IN SR1 DUE TO INTERFERENCE RADIAL PRESSURE OF 11.4 TSI
COMPRESSIVE HOOP STRESS IN DIE INSERT AND SR1 DUE TO INTERFERENCE RADIAL PRESSURE OF 14.4 TSI
COMPRESSIVE HOOP STRESS IN DIE INSERT DUE TO INTERFERENCE RADIAL PRESSURE OF 11.4 TSI
COMPRESSED COMPRESSIVE HOOP STRESS IN DIE INSERT DUE TO INTERFERENCE RADIAL PRESSURE OF 11.4 TSI AND INTERFERENCE RADIAL PRESSURE OF 14.4 TSI
IN WORST CONDITION
SR1 HAS TO WITHSTAND 85.54 - 23.94 = 60.0 TSI TENSILE HOOP STRESS
SR2 HAS TO WITHSTAND 60 TSI TENSILE HOOP STRESS

Fig. 10 *Hoop-stress condition of composite die*

for overload conditions which do occur occasionally in the extrusion operation.

As a general statement the interference between mating rings is of the order of 0.003 in. to 0.004 in. per inch of diameter. In the following pages diagrams are shown of the radial- and hoop-stress conditions of a composite die, Figs. 9 and 10, from which the effect of the shrink rings in reducing the tensile hoop stress at the bore of the die under load will be noted. There is no reduction, however, of the radial compressive stress at the bore of the die. The stress calculations which have been made are based on Lamé's Theorem.

METHOD OF DESIGNING A DIE

Material of Insert—Steel

An extrusion die is designed as a thick cylinder which is subjected to an internal radial pressure.

The known features of the die are :

(*a*) The bore diameter, since the external diameter of the component is known.

(*b*) The external diameter of the die is 4.1 times the bore diameter.

(*c*) The die is subject to an internal radial pressure intensity. The maximum pressure intensity exerted by the extrusion punch on the component during the extrusion load is considered to be transmitted through the component as a hydrostatic pressure. For extrusions this pressure intensity is approximately 120 tons per sq. in., the die is, therefore, considered to have an internal radial pressure intensity of 120 tons per sq. in.

Assumptions made :

(*a*) That failure of the die will occur due to the maximum principal stress, which for any cylinder subjected to an internal pressure is the hoop tensile stress at the inner surface of the cylinder (*see* "Strength of Materials," Morley, page 354).

(*b*) That the die is subject to a static internal pressure equivalent to the maximum stress intensity exerted by the extrusion punch.

The objectives to be achieved when calculating hoop stresses across the section of an extrusion die, built up from a die insert and two shrink rings are:

(i) when subjected to an internal pressure in the die bore, the resultant hoop stresses in the bore of the die insert should not exceed the yield strength of the steel used for the die insert and should have the lowest possible value.

(ii) the maximum hoop stresses in the shrink rings resulting from the internal radial pressure in the die bore and from the pre-stressing of the die insert and inner shrink ring do not exceed the yield strength of the steel used for the shrink rings.

Method of calculating hoop and radial stresses in die.

For calculating the hoop and radial stresses Lamés Theorem for thick cylinders is used,

$$\textit{i.e. Radial stress} = Px = \frac{b}{R^2} - a$$

$$\text{Hoop stress} = Py = \frac{b}{R^2} + a$$

where R is the radius at which Py and Px act and "a" and "b" are constants.

Consider Fig. 7 :

The internal pressure intensity due to work load = 120 tons per sq. in.

$\therefore$ internal radial pressure intensity = $P_{X R_2}$ = 120 tons per sq. in.

The external radial pressure intensity on outside of die = $P_{X R_1}$ = 0

The ratio of radius R_3, R_4 and R_1 to radius R_2 are:

$R_3 = 1.6\,R_2$

$R_4 = 1.6^2 R_2 = 2.56 R_2$

$R_1 = 1.6^3 R_2 = 4.1 R_2$

1. The hoop stresses in the die resulting from the internal radial pressure intensity $P_{X R_2} = 120$ tons per sq. in. are calculated at radius R_2, R_3, R_4 and R_1.

$$P_{XR_2} = 120 = \frac{b}{R_2^2} - a$$

$$P_{XR_1} = 0 = \frac{b}{R_1^2} - a = \frac{b}{4.1^2 R_2^2} - a$$

$$\therefore P_{XR_2} - P_{XR_1} = 120 = \frac{b}{R_2^2} - \frac{b}{16.81 R_2^2}$$

$$120 = \frac{16.81 R_2^2 b - R_2^2 b}{R_2^4 \times 16.81}$$

$$\therefore b = \frac{120 \times 16.81 \times R_2^2}{15.81}$$

$$= 127.8 R_2^2$$

$$\therefore a = \frac{b}{4.1^2 R_2^2} = \frac{127.8 R_2^2}{16.81 R_2^2}$$

$$= 7.59$$

$$\therefore \text{Hoop stress at } R_2 = P_{YR_2} = \frac{127.8 R_2^2}{R_2^2} + 7.59$$

$$= 135.39 \text{ tons per sq. in.}$$

$$\text{Hoop stress at } R_3 = P_{YR_3} = \frac{127.8 R_2^2}{R_3^2} + 7.59$$

$$= \frac{127.8 R_2^2}{2.56 R_2^2} + 7.59$$

$$= 57.49 \text{ tons per sq. in.}$$

$$\text{Hoop stress at } R_4 = P_{YR_4} = \frac{127.8 R_2^2}{R_4^2} + 7.59$$

$$= \frac{127.8 R_2^2}{6.55 R_2^2} + 7.59$$

$$= 27.09 \text{ tons per sq. in.}$$

$$\text{Hoop stress at } R_1 = P_{YR_1} = \frac{127.8 R_2^2}{R_1^2} + 7.59$$

$$= \frac{127.8 R_2^2}{16.81 R_2^2} + 7.59$$

$$= 15.18 \text{ tons per sq. in.}$$

2. The outer shrink ring (R_1 R_4) is now considered. This shrink ring has two functions to perform.

(a) to support the hoop stress $P_{YR_4} = 27.09$ tons per sq. in. resulting from the internal radial stress due to the work load.

(b) to apply a compressive radial stress to the die insert (R_3 R_2) and shrink ring (R_1 R_3) thus reducing the hoop stresses in these rings which result from the internal radial stresses due to the work load.

Considering (a) and (b), yield strength of the steel used for the shrink ring = 60 tons per sq. in. Hoop stress at radius R_4 resulting from work load $= P_{YR_4} = 27.09$ tons per sq. in.

$\therefore$ If yield strength of steel is not to be exceeded, hoop stress from outer shrink ring to apply compressive stresses to rings (R_4 R_3) and (R_3 R_2) $= 60 - 27.09 = 32.91$ tons per sq. in.

Calculations for hoop and radial stresses in outer shrink ring (R_1 R_4) when hoop stress at $R_4 = 32.91$ tons per sq. in.

$$P_{YR}\ (R_1 R_4) = 32.91 = \frac{b}{R_4^2} + a = \frac{b}{6.55 R_2^2} + a$$

$$P_{XR_1}\ (R_1 R_4) = 0 = \frac{b}{R_1^2} - a = \frac{b}{16.81 R_2^2} - a$$

$$\therefore P_{YR_4}\ (R_1 R_4) + P_{XR_1}\ (R_1 R_4)$$

$$= 32.91 = \frac{b}{6.55 R_2^2} + \frac{b}{16.81 R_2^2}$$

$$\therefore b = 155.5 R_2^2$$

$$a = \frac{155.5 R_2^2}{16.81 R_2^2} = 9.25$$

Hoop stress in ring (R_1 R_4) at $R_1 = P_{YR_1}\ (R_1 R_4)$

$$= \frac{155.5 R_2^2}{R_1^2} + 9.25$$

$$= \frac{155.5 R_2^2}{16.81 R_2^2} + 9.25$$

$$= 18.50 \text{ tons per sq. in.}$$

Radial stress in ring (R_1 R_4) at $R_1 = P_{XR_1}\ (R_1 R_4)$

$$= \frac{155.5 R_2^2}{R_1^2} - 9.25$$

$$= \frac{155.5 R_2^2}{6.55 R_2^2} - 9.25$$

$$= 14.40 \text{ tons per sq. in.}$$

$\therefore$ Radial stress on combined ring (R_1 R_2) at R_1

$$= 14.40 \text{ tons per sq. in.}$$

Calculations for hoop and radial stresses in combined ring (R_4 R_2) when radial compressive stress at $R_4 = 14.40$ tons per sq. in.

$$P_{XR_4}\ (R_1 R_2) = 14.40 = \frac{b}{R_4^2} - a = \frac{b}{6.55 R_2^2} - a$$

$$P_{XR_2}\ (R_1 R_2) = 0 = \frac{b}{R_2^2} - a$$

$$P_{PR_2}\ (R_1 R_2) - P_{XR_4}\ (R_1 R_2) = -14.40$$

$$= \frac{b}{R_2^2} - \frac{b}{6.55 R_2^2}$$

$$\therefore b = -17 R_2^2$$

$$a = \frac{b}{R_2^2} = -17$$

Hoop Stress in ring (R_4 R_2) at $R_4 = P_{YR_4}\ (R_4 R_2)$

$$= -\frac{17 R_2^2}{R_4^2} - 17$$

$$= -\frac{17 R_2^2}{6.55 R_2^2} - 17$$

$$= -19.6 \text{ tons per sq. in.}$$

Hoop stress in ring (R_4 R_2) at $R_3 = P_{YR_3}\ (R_4 R_2)$

$$= -\frac{17 R_2^2}{R_3^2} - 17$$

$$= -\frac{17 R_2^2}{2.56 R_2^2} - 17$$

$$= -23.54 \text{ tons per sq. in.}$$

Hoop stress in ring (R_4 R_2) at $R_2 = P_{YR_2}\ (R_4 R_2)$

TABLE II

	Die insert (R_3 R_2)		Inner shrink Ring (R_4 R_3)		Outer shrink Ring (R_1 R_4)	
	Bore R_2	O/Dia R_3	Bore R_3	O/Dia R_4	Bore R_4	O/Dia R_1
Hoop stress due to work load ..	135.39	57.49	57.49	27.09	27.09	15.18
Hoop stress due to shrinkage of outer shrink ring	—34	—23.54	—23.54	—19.60	32.91	18.50
Resulting combined stresses	101.39	33.95	33.95	7.49	60.00	33.68

$$= -\frac{17R_2^2}{R_2^2} - 17$$

$$= -34 \text{ tons per sq. in.}$$

The values of the hoop stresses calculated for the combined die insert and inner shrink ring (R_4 R_2) and the hoop stresses in the outer shrink ring (R_1 R_4) are now summated with the corresponding values of the hoop stresses due to the work load, in Table II.

3. The interference between the shrink rings (R_1 R_4) and (R_4 R_3) at the common radius R_4 is now calculated to ensure that the shrink rings can be assembled at a temperature below that at which the steel is tempered to obtain the required yield strength.

Let E = Youngs Modulus for steel = 14,000 tons per sq. in.

m = Poissons effect.

P_{XR_4} (R_1 R_4) = hoop stress at bore radius R_4 of outer shrink ring (R_1 R_4)

P_{XR_4} (R_4 R_3) = hoop stress at outside radius R_4 of inner shrink ring (R_4 R_3)

and P_{XR_4} (R_1 R_4) and P_{XR_4} (R_4 R_3) = radial stress in each ring at common radius R_4).

Circumferential tensile strain in outer shrink ring (R_1 R_4) at radius R_4

$$= \frac{P_{YR_4}(R_1\ R_4)}{E} + \frac{P_{XR_4}(R_1\ R_4)}{mE}$$

Circumferential tensile strain in inner shrink ring (R_1 R_3) at radius R_4

$$= \frac{P_{YR_4}(R_4\ R_3)}{E} - \frac{P_{XR_4}(R_4\ R_3)}{mE}$$

$\therefore$ Total circumferential tensile strain at radius R_4

$$= \frac{P_{YR_4}(R_1\ R_4)}{E} + \frac{P_{XR_4}(R_1\ R_4)}{mE} + \frac{P_{YR_4}(R_4\ R_3)}{E} - \frac{P_{XR_4}(R_4\ R_3)}{mE}$$

$$= \frac{1}{E}\left[P_{YR_4}(R_1\ R_4) + P_{YR_4}(R_4\ R_3)\right]$$

since P_{XR_4} (R_1 R_4) and P_{XR_4} (R_4 R_3) are equal radial pressure intensities at common radius R_4.

$$= \frac{32.91 + 19.6}{14{,}000}$$

$$= 0.00375 \text{ in. per in.}$$

Coefficient of linear expanson for steel = 0.00001116 in. per in. per ° C.

$\therefore$ Minimum temperature rise to give expansion of 0.00375 in. per in.

$$= \frac{0.00375}{0.00001116} = 336° \text{ C.}$$

For EN.25 steel the tempering temperature to give a yield strength of 80 tons per sq. in. is 450° C.

4. The inner shrink ring (R_4 R_3) is now considered. This ring has two functions to perform:

(*a*) to support the hoop stress P_{YR_3} = 57.49 tons per sq. in. resulting from the internal radial stress due to the work load.

(*b*) to apply a compressive radial stress on the die insert (R_3 R_2) thus reducing the hoop stresses in the die insert resulting from the internal radial stress due to the work load.

The inner shrink ring (R_4 R_3) has been pre-stressed by the outer shrink ring (R_1 R_4) thus from Table I, the resulting hoop stress which has to be supported at radius R_3 = (57.49 — 23.54)

= 33.95 tons per sq. in.

If yield strength of steel used for shrink ring = 60 tons per sq. in., then the hoop stress from the inner shrink ring to apply compressive stresses to the die insert (if the 60 tons per sq. in. is not to be exceeded)

= 60 — 33.95 = 26.05 tons per sq. in.

Calculations for hoop and radial stresses in inner shrink ring (R_4 R_3) when hoop stress at radius R_3 = 26.05 tons per sq. in.

$$P_{YR_3}(R_4\ R_3) = 26.05 = \frac{b}{R_3^2} + a = \frac{b}{2.56R_2^2} + a$$

$$P_{XR_4}(R_4\ R_3) = 0 = \frac{b}{R_4^2} - a = \frac{b}{6.55R_2^2} - a$$

$$P_{XR_3}(R_4\ R_3) + P_{XR_4}(R_4\ R_3) = 26.05 = \frac{b}{2.56R_2^2} + \frac{b}{6.55R_2^2}$$

$$\therefore b = 47.9R_2^2$$

$$\therefore a = \frac{b}{6.55R_2^2} = 7.32$$

Hoop stress in ring (R_4 R_3) at R_4 = $P_{YR_4}(R_4\ R_3)$

$$= \frac{47.9R_2^2}{R_4^2} + 7.32$$

$$= \frac{47.9R_2^2}{6.55R_2^2} + 7.32$$

$$= 14.64 \text{ tons per sq. in.}$$

Radial stress in ring $(R_4\ R_3)$ at $R_3 = P_{XR_3}(R_4\ R_3)$

$$= \frac{47.9R_2^2}{R_3^2} - 7.32$$

$$= \frac{47.9R_2^2}{2.56R_2^2} - 7.32$$

$$= 11.40 \text{ tons per sq. in.}$$

$\therefore$ Radial stress on die insert $(R_3\ R_2)$ at radius R_3 = 11.40 tons per sq. in.

Calculations for hoop and radial stresses in die insert $(R_3\ R_2)$ when radial stress at radius R_3 = 11.40 tons per sq. in.

$$P_{XR_3}(R_3\ R_2) = 11.40 = \frac{b}{R_3^2} - a = \frac{b}{2.56R_2^2} - a$$

$$P_{XR_2}(R_3\ R_2) = 0 = \frac{b}{R_2^2} - a$$

$$\therefore P_{XR_2}(R_3\ R_2) - P_{XR_3}(R_3\ R_2) = -11.40$$

$$= \frac{b}{R_2^2} - \frac{b}{2.56R_2^2}$$

$$\therefore b = -18.7\ R_2^2$$

$$a = \frac{b}{R_2^2} = -18.7$$

Hoop stress in die insert $(R_3\ R_2)$ at R_2

$$= P_{YR_2}(R_3\ R_2) = -\frac{18.7R_2^2}{R_2^2} - 18.7$$

$$= -37.4 \text{ tons per sq. in.}$$

Hoop stress in die insert $(R_3\ R_2)$ at R_3

$$= P_{YR_3}(R_3\ R_2) = -\frac{18.7R_2^2}{R_3^2} - 18.7$$

$$= -\frac{18.7R_2^2}{2.56R_2^2} - 18.7 = -7.31 - 18.7$$

$$= -26.01 \text{ tons per sq. in.}$$

The hoop stresses calculated in the outer shrink ring $(R_1\ R_4)$, inner shrink ring $(R_4\ R_3)$ and the die insert $(R_3\ R_2)$ are now summated with the corresponding values of the hoop stresses due to the work load in the Table III.

2. The interference between the shrink ring $(R_4\ R_3)$ and the die insert $(R_3\ R_2)$ at the common radius R_3 is now calculated to ensure that the ring and insert can be assembled at a temperature below that at which the steel is tempered to obtain the required yield strength.

$P_{YR_3}(R_4\ R_3)$ = hoop stress at bore radius R_3 of shrink ring $(R_4\ R_3)$.

$P_{YR_3}(R_3\ R_2)$ = hoop stress at outside radius R_3 of die insert $(R_3\ R_2)$

and $P_{XR_3}(R_4\ R_3)$ and $P_{XR_3}(R_3\ R_2)$ = radial stress in each ring at common radius R_3.

$\therefore$ Total circumferential tensile strain at radius R_3

$$= \frac{1}{E}\left[P_{YR_3}(R_4\ R_3) + P_{YR_3}(R_3\ R_2)\right]$$

$$= \frac{26.05 + 26.01}{14000}$$

$$= 0.00372 \text{ in. per in.}$$

$\therefore$ Minimum temperature rise to give expansion of 0.00372 in. per in

$$= \frac{0.00372}{0.00001116} = 334^\circ \text{ C.}$$

For EN.25 steel the tempering temperature to give a yield strength of 80 tons per sq. in. is 450° C. This ensures that the ring can be raised to a temperature which allows clearance between die insert and shrink ring for assembly.

Also there is an allowance of 20 tons per sq. in. in the strength of the shrink rings above the maximum hoop stress which allows for variation in the theoretical yield strength of the steel and also for overload conditions which do occur occasionally in the extrusion operation.

The resulting combined stresses in the die in Table II, show that the maximum tensile hoop stress in each of the shrink rings is at the value of 60 tons per sq. in. as planned thus ensuring that each of the shrink rings is fully stressed when the work load is applied to the die bore.

The maximum hoop stress in the die bore has been reduced from 135.39 tons per sq. in. to 63.99 tons per sq. in. by the effect of the two shrink rings on the die insert. This stress of 63.99 tons per sq. in. compares favourably with the tensile strength of the steel used for the die insert of 130 tons per sq. in.

Tungsten-carbide Dies

On very long production runs it may be more economical to manufacture the die inserts from tungsten carbide rather than a 2 per cent carbon, 12 per cent chrome tool steel as discussed above.

TABLE III

	Die insert $(R_3\ R_2)$		Inner shrink Ring $(R_4\ R_3)$		Outer shrink Ring $(R_1\ R_4)$	
	Bore R_2	O Dia R_3	Bore R_3	O Dia R_4	Bore R_4	O Dia R_1
Hoop stress due to work load	135.39	57.49	57.49	27.09	27.09	15.18
Hoop stress due to shrinkage of outer shrink ring	—34	—23.54	—23.54	—19.60	32.91	18.50
Hoop stress due to shrinkage of inner shrink ring	—37.4	—26.01	26.05	14.64	—	—
Resulting combined stress	63.99	7.94	60.00	22.13	60.00	33.68

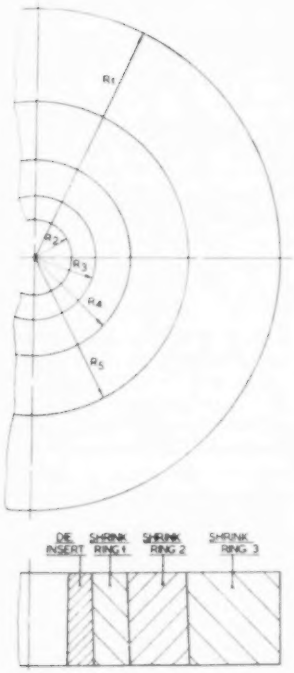


Fig. 11 (left).— Tungsten-carbide die with extra reinforcing ring

Fig. 12 (right).— Radial-stress condition of tungsten-carbide die

The method of designing such tungsten-carbide dies, while basically the same as regards the mathematical theory, must be varied to meet the different conditions.

The first factor to take into account is the very low ductility of tungsten carbide in tension. The designer must, therefore, ensure that there is sufficient compressive stress induced into the insert during the assembly of the reinforcing rings so that there is virtually no tensile stress at the inner face of the die during the extrusion. To ensure this it may be necessary to have in excess of 0,004 in. per in. interference between die rings.

From the figures already given for steel inserts it will be seen that to cater for this degree of interference by shrinking would be out of the question. The temperatures involved would be so high as to leave little strength in the reinforcing rings. The die rings, therefore, are machined with a 2-deg. inclusive taper to predetermined sizes and assembled under a press. The amount of interference can be checked by measuring the distance one ring has been pressed into another. A typical die along these lines is shown in Fig. 11. It will be seen that a third reinforcing ring has been added in order to increase the compressive stress induced into the carbide insert.

This method of die assembly has the added advantage in the fact that the die inserts can be removed and another pressed into place without destroying the reinforcing rings.

The stress distribution over a typical die of this sort is illustrated in Figs. 12 and 13.

The method of assembly is the same as for shrinking, *i.e.* the first reinforcing ring is pressed over the die insert followed by a ring number 2, then ring number 3. The die bore is, of course, machined to size after assembly and is illustrated in Fig. 14.

Lubrication of Tools

No tool design will be successful without proper lubrication of the billet and as far as steel is concerned there is, at present, no better method of lubrication than the conventional zinc-phosphate/-dry-soap lubrication. Some arguments exist as to the amount of phosphate needed for satisfactory performance, it being Continental practice to use lighter coats of 750/1250 mg. per sq. ft., while transatlantic users employ in excess of 3,000 mg. per sq. ft. In this country there are advocates that each particular item has an optimum coating weight. At the author's factory it is standard practice to employ 2,000 mg. per sq. ft. for all types of steel extrusion and, following some years of production experience, there has not been a single instance of pick-up or galling which could be attributed to inadequate phosphating. The heavier and lighter coating weights have, of course, been

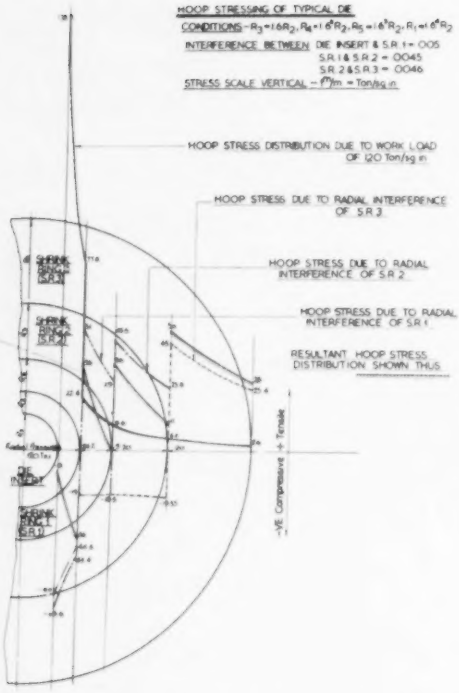

HOOP STRESSING OF TYPICAL DIE
CONDITIONS – $R_3 = 1.6R_2$, $R_4 = 1.6^2R_2$, $R_5 = 1.6^3R_2$, $R_1 = 1.6^4R_2$
INTERFERENCE BETWEEN DIE INSERT & S.R.1 = .005
S.R.1 & S.R.2 = .0045
S.R.2 & S.R.3 = .0046
STRESS SCALE VERTICAL – $\frac{1}{16}$in = Ton/sq in
HOOP STRESS DISTRIBUTION DUE TO WORK LOAD OF 120 Ton/sq in
HOOP STRESS DUE TO RADIAL INTERFERENCE OF S.R.3
HOOP STRESS DUE TO RADIAL INTERFERENCE OF S.R.2
HOOP STRESS DUE TO RADIAL INTERFERENCE OF S.R.1
RESULTANT HOOP STRESS DISTRIBUTION SHOWN THUS
-VE Compressive + Tensile
DIE INSERT
SHRINK RING 1 S.R.1
SHRINK RING 2 S.R.2
SHRINK RING 3 S.R.3

Fig. 13.—Hoop-stress condition of tungsten-carbide die

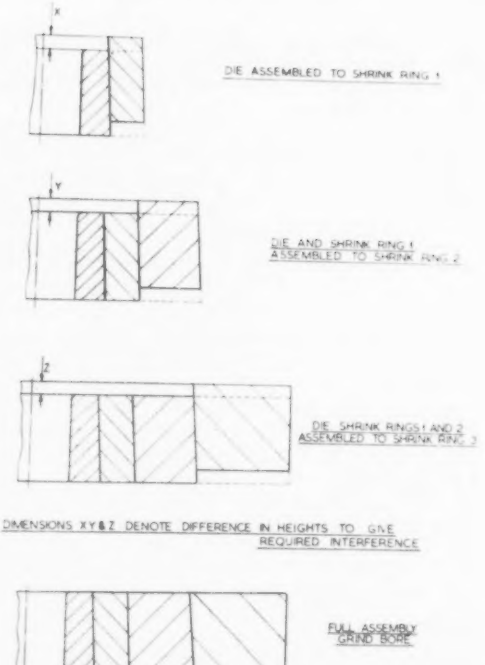
tried but have not recorded any significant improvement in the extrusion load requirements.

With regard to the lighter coating weights, it must be remembered that it requires only one badly lubricated billet to ruin an expensive tool set and while phosphating is a rather expensive operation, the main cost in extrusion lies in handling ; there is very little difference in cost between a lighter coat and the 2,000 mg. per sq. ft. which the author has employed.

Since all trials carried out with different phosphate coatings did not succeed in reducing the punch stress below the normal 120 tons per sq. in., a number of experiments were carried out to assess the performance and feasibility of the various methods which exist of adding a bonded or adsorbed inorganic surface layer on to the tools in order to reduce friction and improve boundary lubrication performance. In no instance, however, can any success be reported in reducing the load requirements. Details of these trials are included hereunder for the benefit of those interested.

Since facilities were readily available the obvious first choice was that of phosphating the wearing surfaces of the tool set. This is not an easy process as the tools are in hardened, highly-alloyed steels. It was found that an acceptable even coat could be obtained in a 70-point zinc-phosphate bath in about 20 minutes, providing that the tools were first solvent degreased to remove any remnant polishing compounds and then given a very short pickle in hot, inhibited 10 per cent sulphuric acid to etch the surface. This was followed by wiping down with white spirit before phosphating. While there was no obvious reduction in load requirements when using phosphated tools with a soap lubricant, graphite or molybdenum disulphide impregnation, it was equally obvious that the surface produced would ensure greater freedom from metal metal contact, and should eliminate galling if such was being experienced. The main objection to the process, however, is the serious degradation of the high polished working surfaces. Normally, in the backward extrusion process, the component remains in the die after extrusion and therefore only a short punch without a stripper bar may be used with obvious advantage. If, however, the punch has a poor surface the component will stick to it and not

Fig. 14.—Build up of tungsten-carbide extrusion die


X
DIE ASSEMBLED TO SHRINK RING 1
Y
DIE AND SHRINK RING 1 ASSEMBLED TO SHRINK RING 2
Z
DIE, SHRINK RINGS 1 AND 2 ASSEMBLED TO SHRINK RING 3
DIMENSIONS X Y & Z DENOTE DIFFERENCE IN HEIGHTS TO GIVE REQUIRED INTERFERENCE
FULL ASSEMBLY OR BORE GRIND BORE

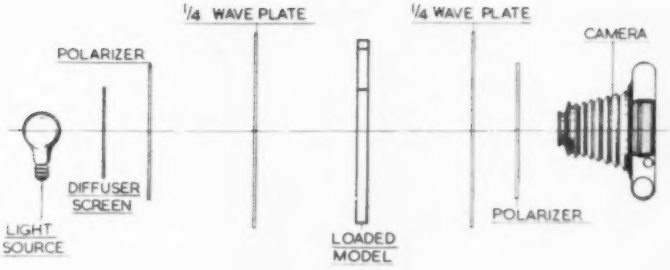


Fig. 15 (left).—Optical system for photo-elastic stress analysis

Fig. 16 (below).—Model tools for photo-elastic stress experiments

remain in the die. It will then be necessary to employ a stripper which in turn entails a longer punch and consequential reduced stability.

These remarks also apply to impregnated oxalate coatings, samples of which were kindly processed for the author by The Pyrene Co. Ltd.

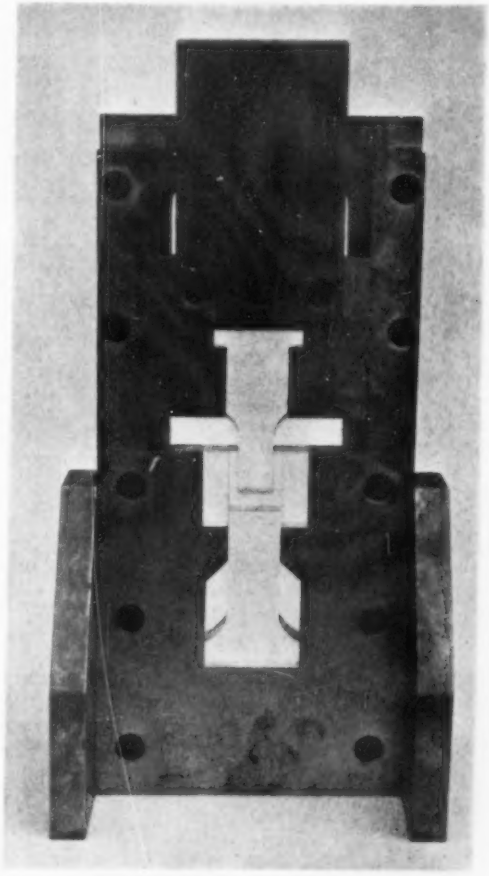
Other methods available include coatings of graphite and molybdenum disulphide. These are lamelar lubricants and possess their properties by virtue of the fact that they cleave very easily in a direction parallel to their crystallographic basal plane and, on cleaving, molecular bonds are released which attract the particle to a clean metal surface where it is adsorbed. Their lubrication properties are directional and depend on the orientation of the plates to the load, the maximum loading capacity being parallel to the plate. Maximum efficiency of lubrication can only be achieved, therefore, after a running-in period with a gradual increase in load in order to align the lubricant to optimum positions. Trials confirmed this as billets lubricated with these substances in addition to the normal soap-phosphate have not shown any reduction in the load requirements. Recently, however, N.E.L. have reported slightly lower loadings with a phosphate-molybdenum disulphide system.

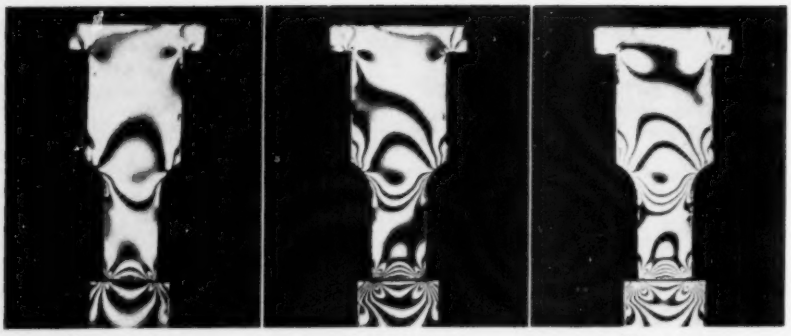
On the other hand, punches and dies already having a bonded graphite or MoS_2 layer are attractive and some effort has been put into attempts to produce such a surface on the tools. Only one feasible method of doing this has been found and this is by the repeated application to the tools in the press of the lubricant suspended in an air drying varnish. It has been demonstrated that if this is repeated some eighty to a hundred times a good surface can be produced. Even so, however, there is no obvious load reduction and although the tools appear to have greater freedom from galling this method is not practiced because of the inordinately long time required for the varnish to dry (some 20 minutes) between each stroke.

Also in hand are trials using the I.C.I. Ltd., patent "SULFINUZ" process—no results are yet to hand.

Punch Design

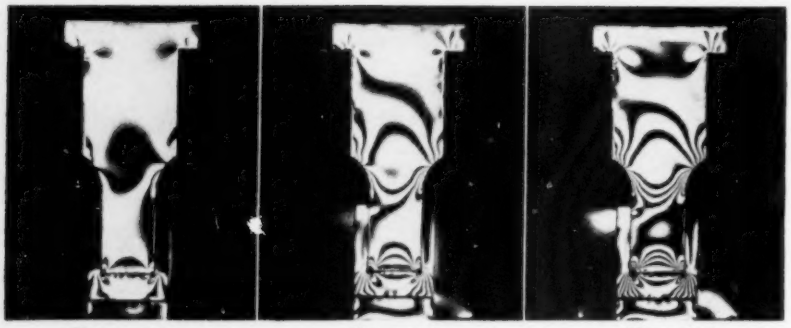
Investigations into the stress distribution in existing tools by photo-elastic methods and design changes indicated by this method can be responsible for much improved tool life. In general, the tool steels used for extrusion are either of the 2 per cent carbon, 12 per cent chromium type or high-speed steels which are hardened to 60-66 Rockwell C., and although there is very little information on the





30 per cent. 60 per cent. 75 per cent.

(a)



30 per cent. 60 per cent. 75 per cent.

(b)

Fig. 17.—Original punch design. (a) Impact with billet (b) Completion of stroke

mechanical properties corresponding to this hardness range, it would probably correspond to a limit of proportionability in excess of 160 tons per sq. in. The limits of cold extrusion practice are in the order of 120 to 130 per tons sq. in. and, therefore, taking into account the extraordinary care which is taken in manufacture to prevent the normally accepted causes of failure—such as grinding cracks, poor surface finishes, etc.—the reasons for early punch bending and fracture are not always readily apparent. However, it is conceivable that while a punch may be loaded to only 65 to 75 per cent of its overall ultimate strength, certain portions of it may, due to uneven stress distribution, be loaded into the plastic region or even over the ultimate. It was felt that a photo-elastic study of the stress systems involved would be profitable and after a little experimental work a suitable rig was designed which incorporated a "two-dimensional" tool and a component made in commercial ½-in. thick Perspex. The optical system is shown schematically in Fig. 15 while the "tools" are fitted into a miniature press which is shown in Fig. 16. This is then loaded in a standard laboratory testing machine.

Existing tool designs were first studied and the stress patterns obtained are shown in Fig. 17. The "fringe" effects are illustrated showing the stress pattern present on loading the Perspex up to 30 per cent, 60 per cent and 75 per cent of its ultimate strength at the point of impact with the billet and also at the completion of the extrusion stroke. These showed that during the application of the load there was no significant change in stress patterns, but there was a change of intensity. All subsequent illustrations are, therefore, those at 75 per cent full load in order to show the maximum effects. Inspection and comment on the fringe patterns can be conveniently divided under the headings of the various tool components.

Die

It is not possible to illustrate the stress pattern in dies by this means as the component cannot be extruded and therefore radial pressures are practically non-existent.

Bolster

As one would expect the stress levels are of less magnitude than in the punch. The bolsters shown are of larger cross-sectional area and, in addition, part of the extrusion load is absorbed by the die.

Punch

This is the most important and interesting item as far as this series of experiments is concerned and

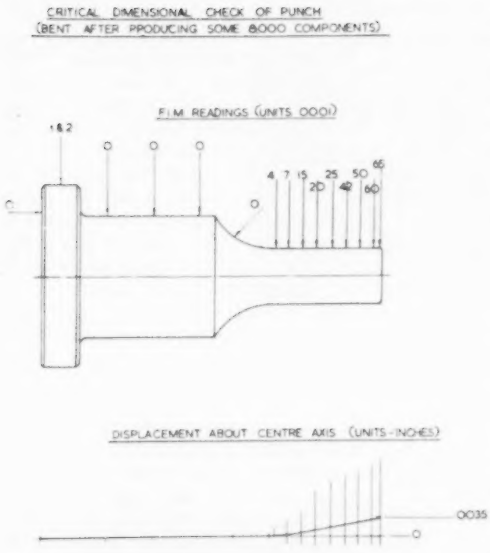


Fig. 18 (above).—Misaligned punch. Uneven stress distribution in misaligned punch together with measurements of a failed punch showing position of bend

Fig. 19 (right).—Fractured extrusion on punch tip

it is evident that there are two regions of intense stress concentration. First, there is an area around the radius of the punch shoulders. This corresponds to the position where tool bending occurs in actual extrusion practice. The stress pattern shown in Fig. 17 is very symmetrical but Fig. 18 illustrates the effect of misalignment of the punch, where the top right side was packed 0.0015 in. lower than the left-hand side. It is very easy to visualize that bending would occur at position A. Fig. 18 also shows the results of measurement of a bent punch, proving that this does occur.

Second, there is a region of stress concentration around the punch nose which is of a rather complex nature and has three nodes in this "two-dimensional model". In three dimensions it will consist of a central area surrounded by an annular region. This is very significant when compared with the actual punch fractures shown in Fig. 19. The first signs of such a fracture are indicated when the components are seen to come off the press, scored by the punch failure defect illustrated in Fig. 20.

With the above observations in mind it was logical to conclude that there was nothing to be gained from this technique as applied to the analyses of the stresses induced in dies and bolsters, and indeed the lack of trouble experienced with these items indicates no real need for it. All subsequent trials were therefore aimed at modifications or changes in punch design which could

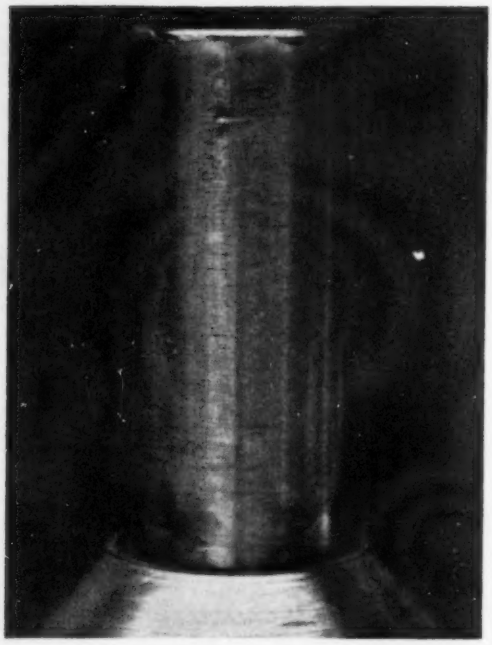


Fig. 20.—Initial indication of punch failure

possibly mitigate the intensity, or eliminate entirely, the two stressed areas referred to. Fig. 21 shows the stress patterns obtained from normal and double the normal shoulder radius together with a punch which was deliberately undercut on the shank to analyze the effect of a common tool-making fault. All examples were taken at the same load level and it will be seen that a larger radius decreases the number of fringes and spreads them over a greater area, which is an obvious advantage. The undercut punch serves to illustrate the concentration of stresses around the position of commencement of the undercut.

A further step in the analysis was to have a conical shoulder profile with large blending radii as illustrated in Fig. 22, but although the stresses are extremely well distributed and free from concentrations, this has the effect of shortening the lateral mounting surface of the punch which in turn leads to increase column distortion on loading. Careful study of the foregoing stress patterns leads to the design of punch shoulder shown in Fig. 23 where there are two equal radii intersecting at tangents lying 60 deg. to the longitudinal axis of the punch. This—as far as photo-elastic models is concerned—is the optimum design showing minimum stress concentrations at the shoulder together with adequate lateral mounting surface. Such extrusion punches are currently undergoing service trials. Also on trial are punches to the general design of Fig. 24 where the working member is a simple cylindrical bar with a separate shrunk-on piece which forms the shoulder and gives lateral support. Although this seems to be the correct method of approach, both as regards design, heat-treatment, and material economy, preliminary results are not too encouraging since it is found that there is relative movement of the two members which induces fretting corrosion leading to early fatigue which, incidentally, is at the position of the asymmetrical loading node at A in Fig. 24. Fig. 25 illustrates a punch which failed in this position, while Fig. 26 depicts a second punch showing severe corrosion after dismantling. However, this method of manufacture is still attractive and the idea is being followed up.

The punch nose form was also studied in some detail and Fig. 27 shows a series of trials which first explored the effect of punch nose corner radius. A practical point here which became evident, is that the manufacture of model punches and exactly matching components is extremely difficult. Any extremely slight change in radii or any protruberance is sufficient to set up additional nodes of stress concentration which can be misleading. The illustrations here, therefore, are put forward to show that changes in the radius do not materially affect the type of stress pattern, although the

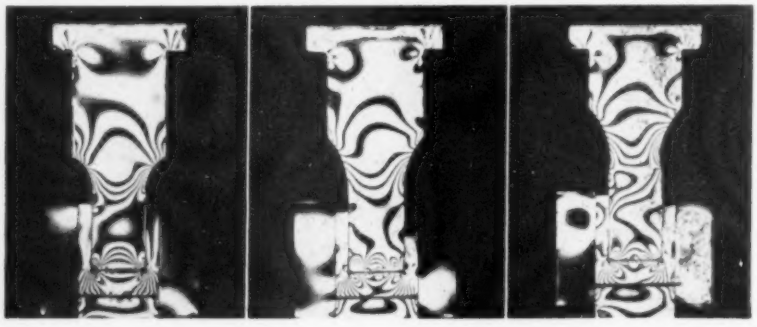


Fig. 21.—Effect of shoulder radius: (left) normal; (centre) 2x normal; (right) undercut

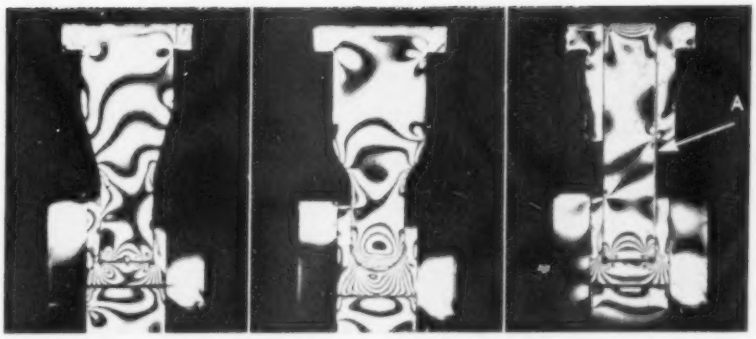


Fig. 22 (left).—Conical shoulder

Fig. 23 (centre).—Optimum shoulder profile

Fig. 24 (right).—Composite punch

relative intensities of the zones may be altered. Even on the completely "spherical" nose the three zones still appear to be evident. If one considers that the central node is produced by pure compression of the tool such as the top of the composite punch in Fig. 24, it is conceivable that the two outer nodes (or annular region in three dimensions) are regions of extreme stress produced by the surface friction of the extruding component flowing around the radius in the opposite direction to the punch movement and causing a bending stress at the corners of the punch nose. If this is accepted the natural conclusion is that, as the body of the punch is nominally loaded to say 75 per cent of its ultimate strength, the extra compressive load applied by the friction will, associated with bending

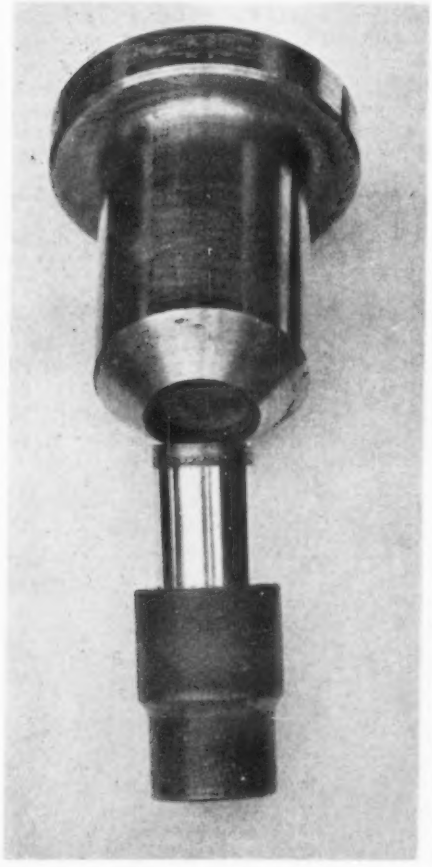


Fig. 25 (left).—Composite punch failed by fatigue in fretting corrosion area

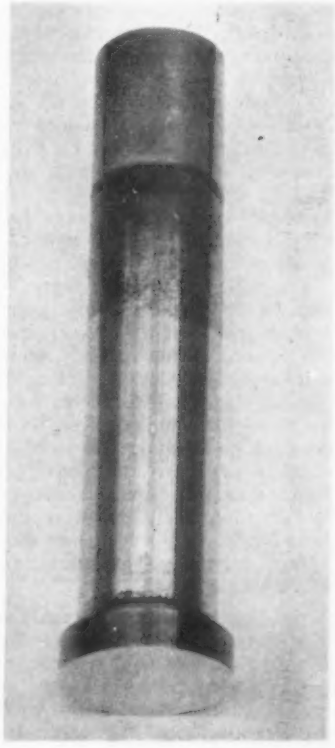
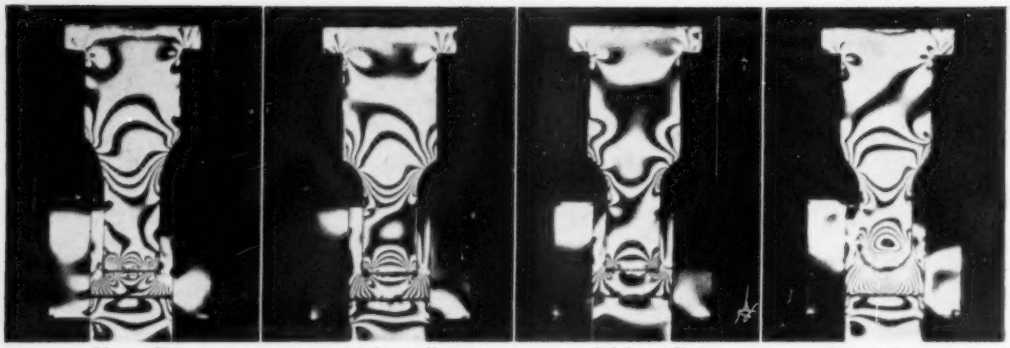


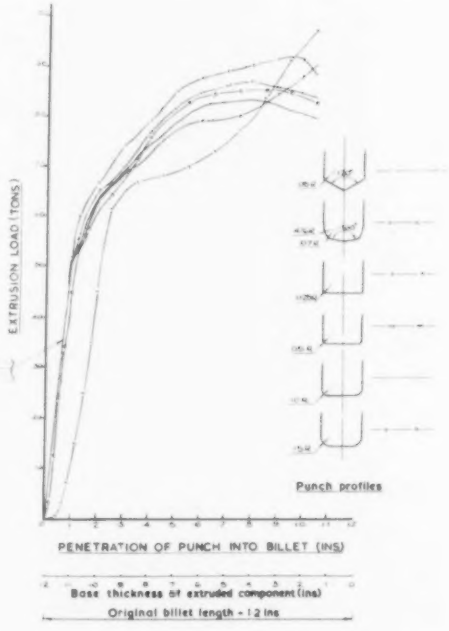
Fig. 26 (right).—Dismantled composite punch showing fretting corrosion



No radius | *0.1 in. radius* | *0.2 in. radius* | *Spherical form*

Fig. 27 (above).—Effect of nose radius

Fig. 28 (below).—Percentage reduction of cross-sectional area — 51.1 per cent. Load diagrams for various punch profiles


EXTRUSION LOAD (TONS)
Punch profiles
PENETRATION OF PUNCH INTO BILLET (INS)
Base thickness of extruded component (ins)
Original billet length - 12 ins

stresses, exceed the ultimate and the cracks produced are due to overload.

The cure or easement of this problem lies probably in the definition of the correct nose profile, but the difficulty in making models to the fine limits required for photo-elastic stress analysis precludes this method of approach. Previously published work on the effect of nose radius on extrusion loads, Fig. 28, together with billet surface deformation experiments show that a radius of 0.1 in. is the optimum for the lowest load. It is thought that a punch will wear to a nose profile most favourable to load distribution, and further experiments to start with this type of profile may be profitable.

Component design demands will often require more complex nose forms than those so far illustrated, and to demonstrate the effect of these on the internal stresses on the punch, the series shown in Fig. 29 are presented. It is evident that each additional step or radius introduces new nodes of stress concentration, any or all of which may be points of incipient failure.

The conclusions to be drawn from the experiments show that the optimum punch design should, as far as the shoulders are concerned, be similar to Fig. 23 where two large radii are used which blend at an angle of 60 deg. to the longitudinal axis of the punch. Regarding the nose, it should be kept as simple as possible, preferably flat and square with a small radius (this often has to be found by trial and error) which gives the lowest press loading and which does not cause lubrication breakdown. A further observation made is that an enormous variation in the stress pattern may be obtained by minute deviations from symmetry, both as regards tool setting and loading.

Tool Steels and Heat Treatment

It is felt that no paper on tool design would be complete without some reference to tool steels, and experience in their use. On the advice of tool steel manufacturers, early work was done using the 2 per cent carbon 12 per cent chrome type of steel,

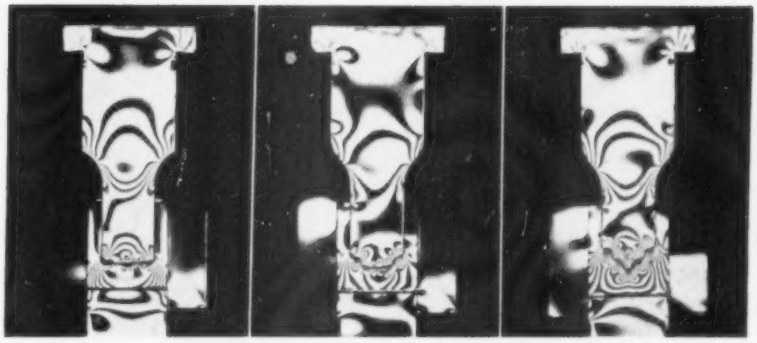


Fig. 29.—Complex nose forms

and dies in this material, hardened and tempered to about 750 V.P.N. are still in common use. With one or two reinforcing shrink rings in B.S.970-En25 at 80-ton tool steel dies are still in service after producing in excess of 150,000 components. The use of this material for punch manufacture, however, gave very erratic results and it was quite common for one punch to crack on the nose after making about 250 pieces, while the next one, made from the same bar of tool steel, heated and ground at the same time, might give in excess of 8,000 components. Some of this variation could be accounted for by press misalignment or malpractice in tool setting, but a large variation in the structure of the steel supplied was also detected and Figs. 30 and 31 obtained from the same piece of steel, show just the amount of variation which can be possible. Various cracked punches showing defects similar to those shown in Fig. 20 were reported to be suffering from grinding cracks. As this type of steel is notoriously difficult to grind, this defect had to be agreed with on certain occasions, but in the majority of instances the so-called grinding cracks were evident only in the area of the punch failure. Surface cracks can certainly be brought about by intense localized frictional heating and it can be considered that cold extrusion produces similar conditions and effects. If such large carbides as those shown in Fig. 31 are

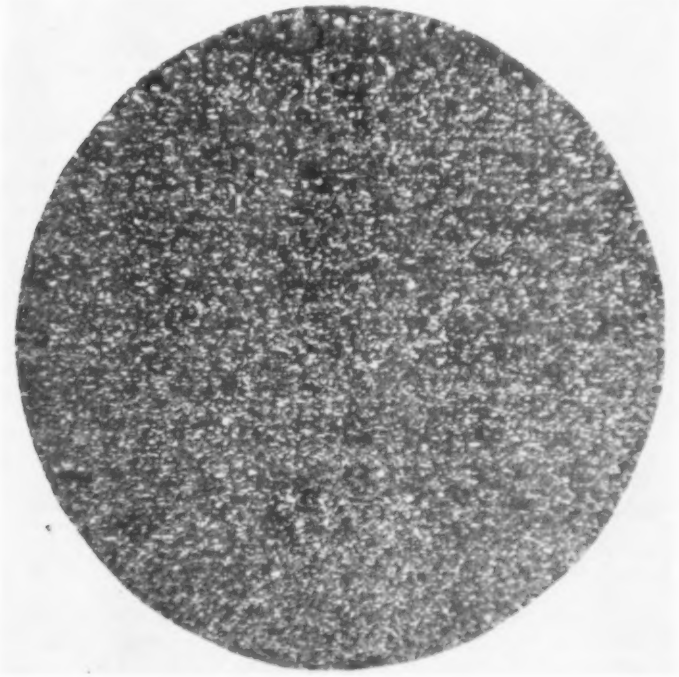


Fig. 30—(× 100). 2 per cent carbon 12 per cent chromium steel showing ideal carbide distribution

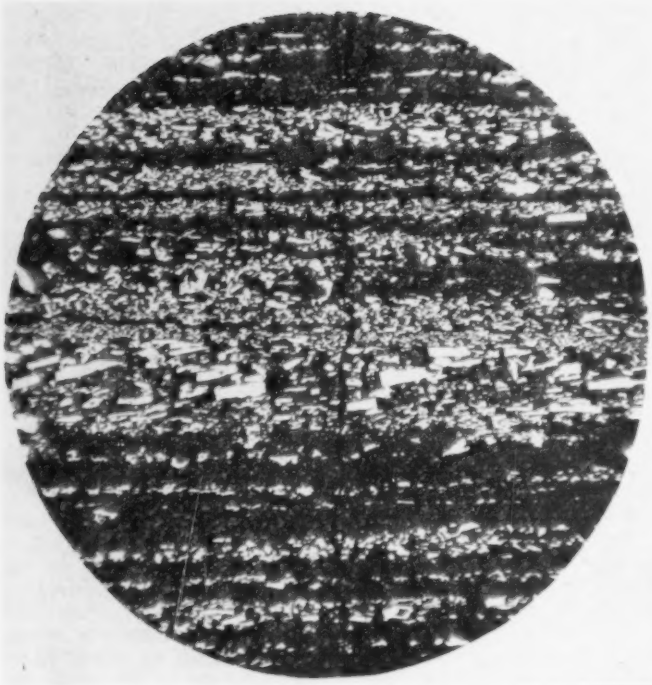


Fig. 31—(× 100). 2 per cent carbon 13 per cent chromium steel showing massive angular carbides and poor distribution

Fig. 32—(× 100). A.R.D.E. Si-Mo steel H & T

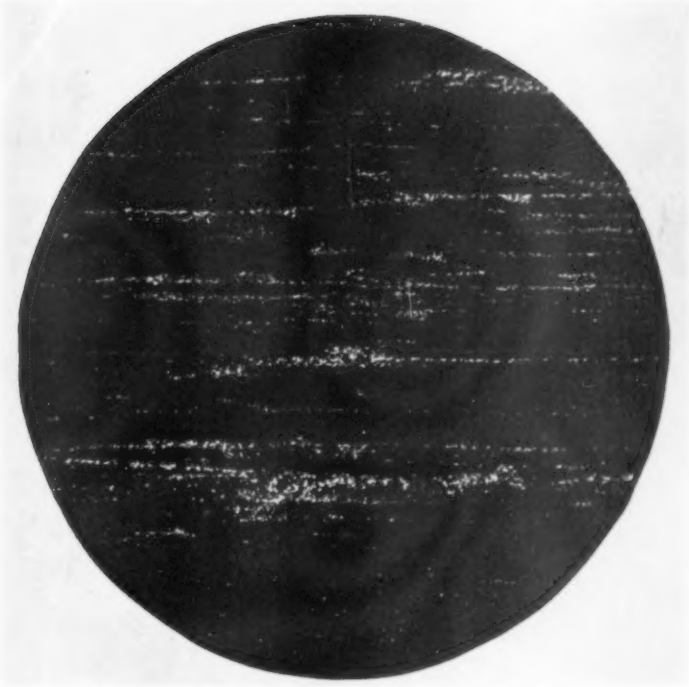


Fig. 33—(× 100). Molybdenum H.S.S. hardened and tempered, showing small well distributed carbides

present, then the difference in expansion coefficients between these and the martensitic matrix will introduce stress raisers and cause cracks to occur. Moreover the very heavy loading of extrusion punches may cause the matrix to yield slightly while the much more brittle carbides break and crack in order to accommodate this movement. It is thought that this is what has occurred on the punch structure shown in Fig. 19, but since the variations in structure can exist laterally as well as along the bar, it is not possible to be dogmatic and say that any particular crack started in a region of massive carbides.

The above observations seemed to indicate that a more homogeneous type of steel with few carbides to be segregated might give better results, and reports from Continental sources suggested that a 5 per cent chrome steel with only 1 per cent carbon was giving reasonable performance. At that time the Armament Research and Development Establishment of the Ministry of Supply was developing a series of new ultra high strength constructional steels, and one of these was capable of being hardened to the same level (750 D.P.N.) as the more exotic tool steels usually employed. It was significant that the punches made from this steel immediately gave a 50 per cent increase on the previous maximum life (12,000 pieces) and failure was by wear on the nose and not by cracking or bending. A typical hardened and tempered structure is shown in Fig. 32 and consists of featureless tempered martensite with the occasional small undissolved carbide.

The composition of this steel is as follows :

C	0.60
Mn	0.56
Si	2.25
S	0.02
P	0.017
Mo	0.75

It has excellent stability during water hardening and the resistance to thermal softening is such that a reasonably high tempering temperature can be employed without undue loss in hardness. In common with all high silicon steels it is particularly prone to decarburisation during heat treatment, and double the normal grinding allowances must be employed. The cost of this steel compared very favourably with conventional tool steels and although it has now been superseded as a punch material, it is used in non-wearing heavily loaded parts of the tool set with satisfactory performance.

It had long been recognized that high-speed steel from a compression strength point of view was an ideal punch material. Our early trials using this material, however, always ended in failure after a very short run. Owing to the inherent brittleness of this type of material such punch failures were

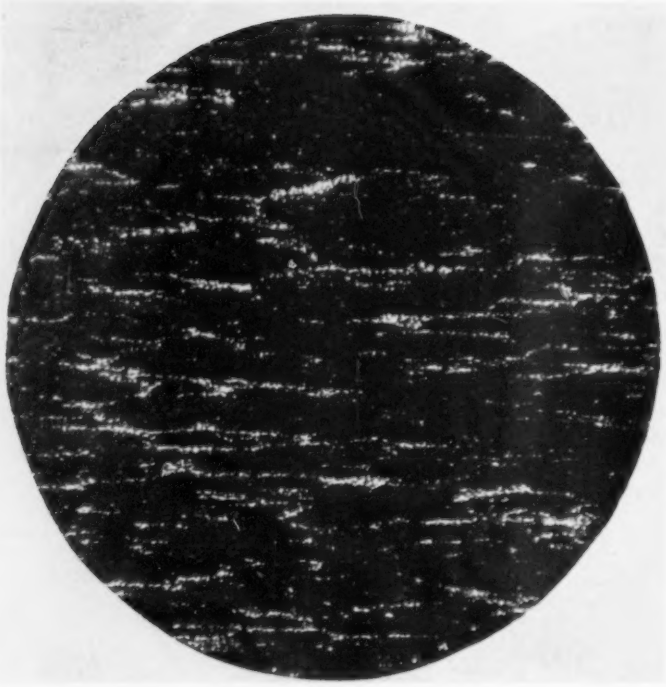


Fig. 34.—Molybdenum H.S.S. showing maximum amount of segregation found in the special cyclone 56 (English Steel Corp. Ltd.)

quite alarming as the tool shattered into many pieces and strict precautions were necessary in order to ensure the safety of the operators. A careful examination into the accuracy and stability of our presses and tools showed that it was possible for the punch to be called upon to withstand appreciable bending during the working stroke. There was no doubt that the introduction of these bending stresses were the main cause of the premature failures, and it was decided, therefore, that no effort should be spared in preparing a tool set-up which ensured maximum accuracy and rigidity. Trials were then carried out using a 5 per cent molybdenum 6 per cent tungsten high strength steel specially produced for this purpose by the English Steel Corporation rolling mills, heat treated to 780 D.P.N. The increase in tool life was immediate, more than 50,000 pieces per punch being obtained regularly.

The carbide distribution in this H.S.S.—Fig. 33—is excellent, with only the occasional segregation as in Fig. 34, but even so these do not contain any really massive primary carbides. It is the opinion that this feature is mainly responsible for the excellent life obtained on this punch material.

Following the considerable success obtained with H.S.S. punches in the new improved tool set, further punches were made from 2 per cent carbon, 12 per cent chrome and tried out comparatively. It was found that their life was an improvement on previous performance insofar as punches were more consistent, but their maximum life still remained low, at about 8,000 pieces.

Now that reasonably consistent and useful punch life is being obtained, we can explore the possibilities of the benefits which can be obtained from heat treatment variations, and avenues to be explored in the future are—the effect of sub-zero treatments, multiple temperings, martempering and the like. Although most of these methods have been tried out in the past it is our belief that the variations in the tool steel masked any possible benefits which could have been and were obtained from such treatments.

DEVIATIONS OF COMPONENTS FROM TOOL DIMENSIONS

One of the advantages claimed for cold extrusion is the accuracy of the components produced and the accompanying saving in material. However, due to the high intensity of stress induced during the extrusion stroke, both the punch and die deform elastically and the resulting components differ dimensionally from the manufactured tool sizes. This was discussed in a paper "The Cold Extrusion of Steel" given to the Iron and Steel Institute in

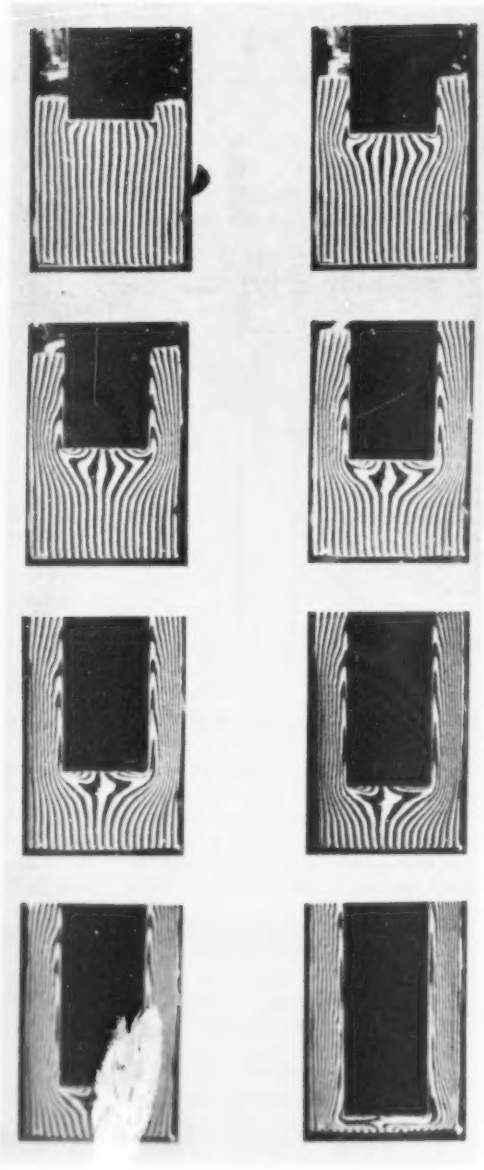
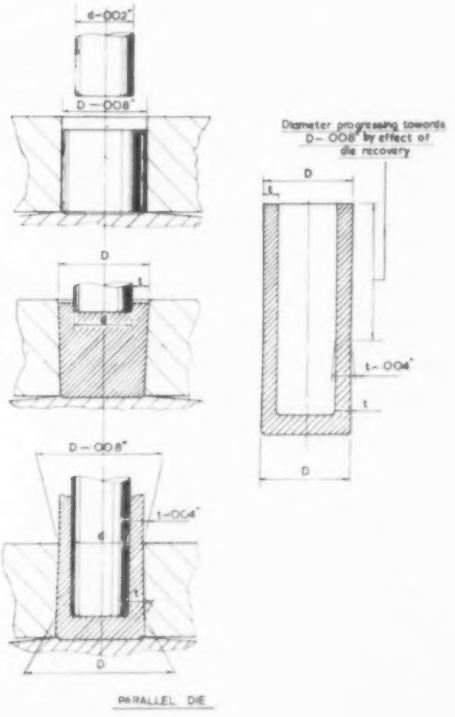


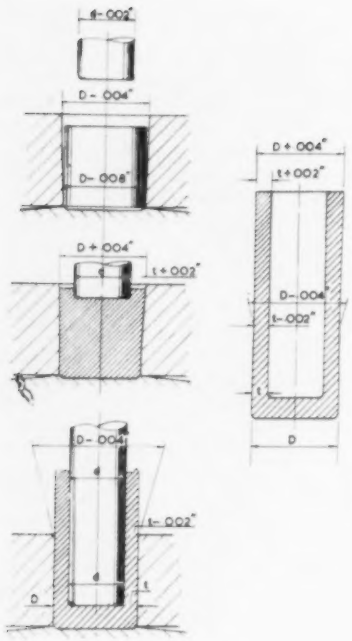
Fig. 35 (above).—Laminated Plasticene models showing change in angle of metal flow

Fig. 36 (right).—Effect of the expansion and recovery of the die

1959 but as it is so important to correct tool design it can bear repetition.

"At first extrusion impact, the mouth of the die is forced to expand and, depending upon the dimensional aspects, the conformity and the method of securement of the die, the expansion at the mouth may, on first impact, be greater than that at the base diameter. However, as extrusion proceeds the effect is to make the die diameter expand progressively downwards through its depth, while the mouth of the die attempts to some degree to recover its original diameter. While this is occurring, the upper porting of the punch shank and the nose of the punch are increased in diameter under load and as a consequence of the choking effect at the die mouth frictional resistance to flow upwards becomes very high. The effect of the expansion and recovery of a die is shown in Figs. 36, 37, 38 and 39 but is perhaps best illustrated in the production of a high-strength aluminium-alloy component which was produced on a Herlan press. This component (*see* Fig. 40) was produced from a tool set-up, as per Fig. 41. The interesting facts about this component is that it is waisted in the centre and it is clear from deduction that at the commencement of extrusion the die expanded at the mouth more than it did at the base. An analysis of the tool set up

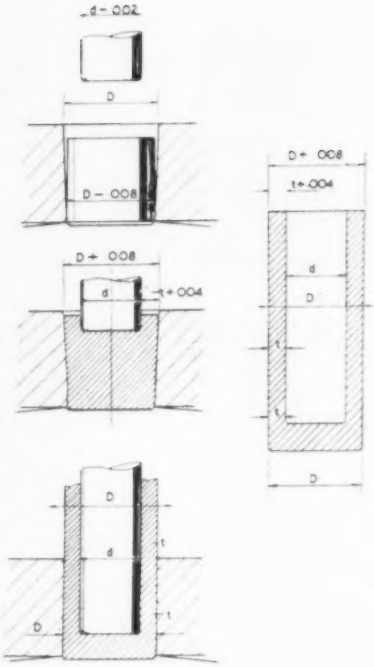




DIE TAPERED 004 IN LENGTH

Fig. 37 (left).—Effect of the expansion and recovery of the die

Fig. 38 (right).—Effect of the expansion and recovery of the die



DIE TAPERED 008 IN LENGTH

shows this to be quite possible. An extrusion lip on the punch 0.024 in. greater in diameter than the punch shank permitted full recovery of the die mouth as extrusion proceeded.

This deviation from tool size warranted further study; Table IV gives the results obtained from six components taken at random from a production run. The punch was made from H.S.S. and the die insert from 2 per cent C., 12 per cent Cr. Tool steel.

It will be seen that for the six samples the outside diameter is remarkably constant, varying about 0.005 in. larger than the bore diameter of the die at rest. The trend is for the outside diameter to taper very slightly from the top to the bottom of the extrusion.

The inside diameter is also reasonably constant for six components, being about 0.0015 in. larger than the punch diameter. Again, there is a slight taper and the majority trend is for the hole to be larger at the top.

Table V gives the results when a die insert of tungsten carbide is substituted for the steel die and the same punch is used.

The outside diameter is again constant for the samples but only about 0.0015 in. larger than the

Table IV.—Deviation of components from tool size Steel punch and die

STEEL DIE 1.1623 DIA STEEL PUNCH .8022 DIA

SAMPLE No	OUTSIDE DIAMETER	DEVIATION FROM TOOL SIZE		INSIDE DIAMETER	DEVIATION FROM TOOL SIZE	
1 TOP	1.1671	.0048	INCREASE	.8030	.0008	INCREASE
BOTTOM	1.1675	.0052	INCREASE	.8035	.0013	INCREASE
2 TOP	1.1665	.0042	INCREASE	.8040	.001	INCREASE
BOTTOM	1.167	.0047	INCREASE	.8033	.0011	INCREASE
3 TOP	1.1666	.0043	INCREASE	.8036	.0014	INCREASE
BOTTOM	1.167	.0047	INCREASE	.8030	.0008	INCREASE
4 TOP	1.1667	.0044	INCREASE	.8037	.0015	INCREASE
BOTTOM	1.1671	.0048	INCREASE	.8027	.0005	INCREASE
5 TOP	1.167	.0047	INCREASE	.8035	.0013	INCREASE
BOTTOM	1.1672	.0049	INCREASE	.8027	.0005	INCREASE
6 TOP	1.1666	.0043	INCREASE	.8037	.0015	INCREASE
BOTTOM	1.1674	.0051	INCREASE	.8039	.0017	INCREASE

Table V.—Deviation of components from tool sizes Tungsten carbide die—steel punch

TUNGSTEN CARBIDE DIE 1.1622 DIA H.S.S. PUNCH .8022 DIA

SAMPLE No	OUTSIDE DIAMETER	DEVIATION FROM TOOL SIZE		INSIDE DIAMETER	DEVIATION FROM TOOL SIZE	
1 TOP	1.164	.0018	INCREASE	.8035	.0013	INCREASE
BOTTOM	1.1638	.0016	INCREASE	.8023	.0001	INCREASE
2 TOP	1.1638	.0016	INCREASE	.8038	.0016	INCREASE
BOTTOM	1.1634	.0012	INCREASE	.8023	.0001	INCREASE
3 TOP	1.1638	.0016	INCREASE	.8033	.0011	INCREASE
BOTTOM	1.1635	.0013	INCREASE	.8025	.0003	INCREASE
4 TOP	1.1638	.0016	INCREASE	.8033	.0011	INCREASE
BOTTOM	1.1633	.0011	INCREASE	.8023	.0001	INCREASE
5 TOP	1.164	.0018	INCREASE	.8035	.0013	INCREASE
BOTTOM	1.1635	.0013	INCREASE	.8020	.0002	DECREASE
6 TOP	1.164	.0018	INCREASE	.8035	.0013	INCREASE
BOTTOM	1.1633	.0011	INCREASE	.8023	.0001	INCREASE

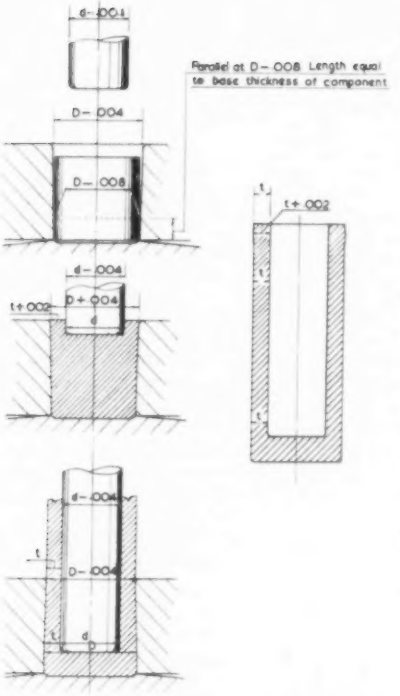
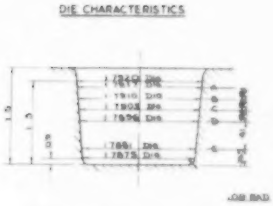
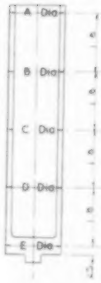


Fig. 39 (left).—Effect of the expansion and recovery of the die



COMPONENT CHARACTERISTICS



Diameter		Waisting Effect	Comparison of compr at 100°C against die at rest
Cold	At 100°C		
1·7919	1·7942	+ 0108	+ 0025
1·7848	1·7871	+ 0037	– 0039
1·7817	1·7840	+ 0006	– 0063
1·7811	1·7834	0	– 0062
1·7899	1·7922	+ 0088	+ 0041

Fig. 40 (right).—Diagram showing the effect of the preferential expansion and contraction of the die as extrusion proceeds. Material extruded 2.25 per cent magnesium % aluminium alloy; billet size 1.785 in. dia. × 1.305 in. long; hardness prior to extrusion 50 V.P.N.

die bore at rest. This is, of course, to be expected as the Young's Modulus for tungsten carbide is approximately three times that of steel, and therefore, steel should strain elastically three times as much as tungsten carbide under similar stress conditions.

Here again the trend is for a slight taper although reversed to that shown in Table IV.

The inside measurements of the six samples show that the deviations from tool size and the taper follows very closely the pattern shown in Table IV.

Table VI gives the results obtained from a punch and die both made of tungsten carbide. Those of the outside diameter are almost identical with Table V and the inside diameter is an almost exact reflection of the outside diameter but with the deviations reduced.

It seems apparent that during the extrusion stroke the die expands elastically under the radial load. This radial load appears to increase as the extrusion stroke progresses, due to the fact that the angle at which the metal flows out from under the extrusion punch approaches the horizontal plane as the base thickness is reduced. This can be illustrated by

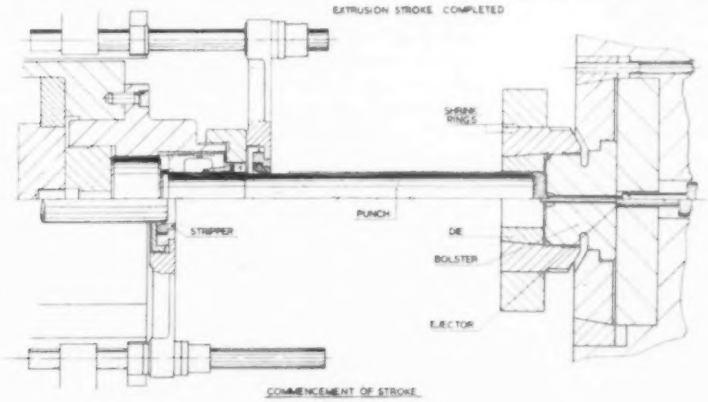


Fig. 41.—Tooling for light-alloy backward extrusion

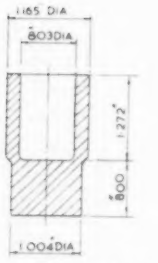
TUNGSTEN CARBIDE DIE 1.622 DIA TUNGSTEN CARBIDE PUNCH .8053 DIA

SAMPLE No		OUTSIDE DIAMETER	DEVIATION FROM TOOL SIZE		INSIDE DIAMETER	DEVIATION FROM TOOL SIZE	
1	TOP	1.164	.0018	INCREASE	.8055	.0002	INCREASE
	BOTTOM	1.1635	.0013	INCREASE	.8050	.0003	DECREASE
2	TOP	1.164	.0018	INCREASE	.8055	.0002	INCREASE
	BOTTOM	1.1637	.0015	INCREASE	.8052	.0001	DECREASE
3	TOP	1.164	.0016	INCREASE	.8055	.0002	INCREASE
	BOTTOM	1.1635	.0013	INCREASE	.8050	.0003	DECREASE
4	TOP	1.164	.0018	INCREASE	.8055	.0002	INCREASE
	BOTTOM	1.1635	.0013	INCREASE	.8050	.0003	DECREASE
5	TOP	1.164	.0018	INCREASE	.8055	.0002	INCREASE
	BOTTOM	1.1635	.0013	INCREASE	.8050	.0003	DECREASE
6	TOP	1.1636	.0014	INCREASE	.8057	.0004	INCREASE
	BOTTOM	1.1637	.0015	INCREASE	.8047	.0006	DECREASE

Fig. 42 (right).—Typical backward extrusion used for determination of tool cost

Table VI (left).—Deviation of component from tool sizes—Tungsten carbide punch and die

Tables VII and VIII (below).—Cost of tools for items illustrated in Fig. 42



BILLET SIZE 1.162" DIA X 1.276" LONG

ITEM No	TOOL	MATERIAL		COST £ - s - d	TOOL LIFE
1	PUNCH Solid type		6%W 5%Mo 2%V H.S.S.	6 - 2 - 0	75,000
2	PUNCH Composite type	PUNCH	6%W 5%Mo 2%V H.S.S.	12 - 6 - 3	25,000
		ADAPTOR	En 25 STEEL		
3	PUNCH Composite type	PUNCH	TUNGSTEN CARBIDE	30 - 0 - 0	1,500,000
		ADAPTOR	En 25 STEEL		
4	DIE Steel insert	INSERT	2%C 12%Cr STEEL	28 - 1 - 9	200,000
		Shrink Rings	En 25 STEEL		
5	DIE Tungsten Carbide	INSERT	TUNGSTEN CARBIDE	39 15 0	1,500,000
		Shrink Rings	En 25 STEEL		
6	BOLSTER		2%C 12%Cr STEEL	8 - 18 - 2	75,000

	TOOLS	ITEM Nos	TOTAL COST £ - s - d
a	STEEL PUNCH, DIE & BOLSTER	1,4 & 6	53 - 1 - 11
b	TUNGSTEN CARBIDE PUNCH & DIE INSERT & STEEL BOLSTER	3, 5 & 6	178 - 13 - 2
c	STEEL PUNCH, TUNGSTEN CARBIDE DIE - INSERT & STEEL BOLSTER	2, 5 & 6	151 - 9 - 5

means of laminated Plasticene billets as shown in Fig. 35. Thus the component is extruded slightly larger towards the end of the extrusion stroke, both inside and outside diameters being affected.

When the extrusion load is removed on the reversal of the press, the die tends to recover back to its normal diameter, being prevented from going all the way by the now work-hardened component which remains inside the die. The die, therefore, does not return to its manufactured size until the extractor removes the component from the die bore and thus the outside diameter is larger than the tool size. As would be expected this partial recovery also affects the internal dimensions insofar that the bore of an extruded component is always tapered being larger at the mouth than at the base. The difference in Young's Modulus for the two materials used for the tools accounts for the difference in the deviations quoted. It is interesting to note the constancy of the variations resulting from the tungsten carbide tools (Table VI).

TOOL COSTS AND EXPECTED LIFE

No paper on tooling would be complete without some reference to tool costs per component produced.

Referring back to Fig. 1 as a typical backward extrusion set up to produce a component as in Fig. 42, the expendable items of tooling would be (*a*) the punch, (*b*) the die, (*c*) the bolster.

The punch can be either of the solid or composite design discussed in the previous chapter and made from H.S.S. or tungsten carbide.

The die insert can be made either from 2 per cent C., 12 per cent chrome steel or tungsten carbide with two reinforcing rings in the case of the steel insert and three rings in the case of tungsten carbide.

Table VII lists these expendable items and gives some idea of the cost to manufacture together with an average number of components produced. In the case of the tungsten carbide items the tool life quoted is estimated as sufficient components to run the tools to destruction have not been made.

Item 2, the composite type punch, has a much shorter life due to the fretting corrosion previously discussed. The idea behind this design was to produce a cheaper tool (a reduction in the diameter of H.S.S. bar necessary) and avoid any change of section (hence stress concentration) near the middle of the punch. Unfortunately, this design has produced this other great disadvantage which must be overcome if it is to be economic.

Table VIII shows the collected costs of these items for three types or combinations of materials and illustrates that before tungsten carbide is introduced comparatively large orders must be envisaged.

While the initial costs of tooling for cold extrusion are extremely high in comparison to hot stamping—drop forging, etc., the cost per component produced can be exceedingly small.

Acknowledgements

The author would like to place on record the valuable help he has received from his staff in the production of this paper and in this connection would particularly thank Messrs. Ketchin, Walmsley and George for their great assistance in carrying out all the field work. The author's thanks are also extended to The Pyrene Co. Ltd., the English Steel Corpn., and all the other concerns whose assistance has been constant and so freely extended.

COLD FORMING OF STEELS

By F. GRIFFITHS*

A paper presented at the Special Conference on the Cold Extrusion of Steel, organized by the Institute of Sheet Metal Engineering, at the City Hall, Sheffield, November 21-23, 1960

THE cold forming of metals has been used by the engineering and production industries for many years, but it has been carried out mainly on materials which are of a non-ferrous nature. Since the beginning of the last World War, a considerable amount of work has been done in different ways to form steels into various shapes while it is cold.

The main emphasis has been on extrusion, either continuously through a die or in a semi-open die, which has either resulted in bars of cross-sectional profiles or the production of components of a cylindrical nature. To-day, a very considerable amount of work is being done around the principle of producing steel components out of closed dies similar to those used in the hot forge, and a very large amount of success has been achieved.

In this paper the general aspect of this work, its general problems and the nature of the economics which are involved will be discussed. While a certain number of examples will be illustrated and explained, the object will be to look at the process as a whole, and not as a series of detailed specific problems.

In the year 1953 a very comprehensive conference, lasting six days, was held in England by the Sheet and Strip Metal Users' Technical Association (now the Institute of Sheet Metal Engineering), at which a very large number of papers was presented around the knowledge that existed at that time, largely forward and backward extrusion of metals into cylindrical form components. The conference, as a whole, remained much too technical and the public findings were of such a nature that industry in Great Britain seemed completely unable to absorb any of the results of the proceedings into practical action.

Some three to four years ago the British Motor Corporation moved into the cold forming of components as a result of the very considerable wastage of steel which is caused by the hot-forging process as generally used by the automobile industry to produce the components they use, and by the waste on components produced out of bar automatic machinery.

It was found, in Great Britain, that industry was not using the cold-forming process for steel components and knew very little about it, but a certain amount of work had been done at one of the ordnance factories. Because of industry not having done any work on the cold forming of steels, and because of the extremely technical nature of the 1953 conference, the British Motor Corporation had to start entirely "from scratch" and work its way into cold forming to find out what was really required and what could be done with the process, and what were the economics.

The work that had been done in Germany on the cold forming of steels was of a very interesting nature, and although certain German firms were approached, it was found that the prices they were quoting for various components prevented purchasing. Common sense dictated that the amount of material that would be used if a component was made by a cold-forming process would be very

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Fig. 1.—Prop.-shaft flange: This component has the spline hole machined in and has certain diameters and faces machined true to the hole. Billet, 3.8 in. long and 1.592 in. dia. Finished flange dia., 3.375 in. Material saving, cold extrusion versus hot forging, 11¼ oz. per component

Fig. 2.—Driving flange: There is an annealing operation between the second preform and the final forming operation. The component has a hole machined into it and has certain diameters and faces machined true to the hole. Also, this component, which is made of a 70-ton hardening steel as a hot forging, which produces considerable machining problems, can be made of a lower grade steel by taking advantage of the work-hardening properties of the cold-forming. Billet, 3.8 in. long × 1.8125 in. dia. Material saving, cold extrusion versus *hot forging, 6¼ oz. per component*

much less than if they were made by the hot-forging method, or if they were made out of bar. It could also be seen that cold forming could be attempted, generally speaking, where hot forging could not, such as in gear teeth and splined bores, with considerable saving in the machine shop. It was also obvious that not only would less material be used giving considerable savings, labour would also be less than by using the hot-forging process, running costs too, exclusive of capital amortization, would be less. It was decided, therefore, to pursue the process as an independent exercise, not including savings which would be made in the machine shop, so that a true evaluation could be obtained.

The 1953 conference in England, the work at the ordnance factory, and the work done in Germany and in America, showed that the cold forming of steels was a practical proposition. The problem that presented itself was to make the process thoroughly economic in its own rights. This, to a large extent, has been done, and it can be firmly stated that the cold forming of steel components can take the place of steel components produced by the hot-forging processes, and does not depend on what savings can be made in the deletion of machine-shop operations.

The results of the investigation into cold forming have shown that the difficulties do not lie in the actual cold-forming operation, but are involved in the cost of the capital equipment and the manufacture of pellets, and solid and hollow billets. It appears that in relation to the cold-forming process, production engineers have been thoroughly frightened to death by the long-haired research workers' end results. In fact, the 1953 conference instead of opening out the process so that industry could absorb it did just the opposite.

One of the first problems that arises with cold forming is when the process is used for the purpose of component production, and is, what is to be the final form to be produced by the process and how much modification to the fundamental billet has to take place in order that this final operation may be done. There are, as yet, very few experienced operators and very few engineers with the practical knowledge involved in making an accurate assessment regarding this. For some time to come the stage or stages between billet and final forming will be in the nature of a guess, which, of course, will be tried out before final production machinery is purchased and installed.

It is very important to-day that any producing unit which is thinking of entering cold forming, should instal at least a 1,500-ton hydraulic press, secondhand or new, in order that the guess may be tried out and proved. There has been, in Great Britain, an effort between the Production Engineering Research Association and a press manufacturing company to produce a press for this purpose, but the end result has turned out to be a press of a

Fig. 3.—2nd-speed synchronizer: The making of the hollow billet is not shown here, as the method has not been finally decided. The final cold-worked component has machining done to each end as well as a shaving operation on the teeth to true them with the hole. This component is now made out of a hot forging in 90-ton yield-point steel, and will now be made out of a 20-ton deep-drawing steel, again using the work-hardening properties of cold forming. Billet, 1.875 in. long × 3 in. dia. Finished dia. over all teeth, 2.625 in. Material saving, cold extrusion versus *hot forging, 8 oz. per component*

Fig. 4.—2nd-speed mainshaft gear: The production of the hole in this billet is used as a means of giving useful shape to the preform. An annealing operation is also used before the final operation. Billet, 1.410 in. × 2.65 in. dia. Finished dia. over all teeth, 3.25 in. Material saving over hot forging, 10 oz. per component

ridiculous capital cost and therefore of no use to industry. The British Motor Corporation has installed an old war-time hydraulic press, obtained at a very low figure, and it has been found extremely satisfactory for the experimental work which has been done.

It is strongly recommended that work in the cold forming of steels shall be carried out on hydraulic, not mechanical, presses and the problems of the economics concerned with this will be dealt with later in this paper. The advantage, particularly of a hydraulic press in the initial stages of proving what can or cannot be done in a practical way, is that pressures can be maintained over long strokes. Pressure and stroke can also be varied on such a press. There is also a considerable amount of overemphasis on the finish required on the working areas of the tools. It has been said that very long polishing procedures are necessary; this is not so. It is only necessary to finish tools so that scratches cannot be seen with the naked eye. It is very important on tools producing finished or near finished sizes for shrink rings to be put around the outside of the die, so that pressures on the die are normalized during the actual forming process.

There is a conception in various quarters that tools for cold forming are necessarily very expensive; this again is not so. The cost of these need only be the same as the hot forging die cost, plus a small amount of cost for polishing.

It is proposed now systematically to describe the process required for the cold forming of steels, and look at what is necessary, what is actually required, and the general economics of the operations involved in the cold forming of a steel component. Before continuing to do this, it is advisable to understand that there are fundamentally two types of components which are normally required and which involve a certain line of activity to arrive at a satisfactory economic end result. These two types of components are the regular shaped components which are more or less circular in form, the tools for which can be produced by the normal tool-room methods of turning, milling, boring, grinding, gear cutting, etc., and the irregular shaped component, the dies for which would be produced by the normal die-shop method of marking out, machining on a die-sinking machine, and then finishing off on a bench, using plate gauges as the main means of measurement. The fundamental differences between the manufacture of cold-forming of these two types of components are in the manufacture of the preforms and the capital cost of the plant into which the tools are to be placed. These will be dealt with in their respective places in this paper.

The problems required to be resolved about the work that has to be done to make a component by the cold forming of steel into dies, form themselves into a fairly simple group of fundamental issues, such as pellet, and solid or hollow billet manufacture, the exact nature of preforms, the final shape of the component out of the last die, the effective lubrication of the metal surfaces, the economic annealing, and finally, the right type of capital equipment with the right capital cost.

This last problem of the right piece of capital equipment, both in type and cost, has not been faced up to by any known production unit, and there is no doubt that the solution of this problem is by far the most important issue which has to be faced. Generally speaking, it has been known since the cold forming of steel or any other metal was embarked upon, that the right piece of capital equipment would be one that was operated by hydraulic power, but like much of the world's

Fig. 5.—Differential pinion: The making of the hollow billet is not shown here as the method has not been decided. This component is produced to size by cold forming, except for truing up the bore, the bearing diameter, and the back-face, which is done by machining. Billet, 1.575 in. long × 2 in. dia. Finished dia. over all teeth, 2.75 in. Concentric hole, 0.984 in. dia. Material saving over hot forging, 9 oz. per component

capital equipment, the hydraulic press, which started its life in the early period of the industrial revolution as a thoroughly simple unit, has been elaborated to an almost ridiculous extent in order to allow the salesmen of the press the widest possible field of sale. The world to-day is suffering to an enormous extent because of this over-development in all types of producing machinery.

Because of the cost of a hydraulic press, the pioneers in cold forming have tried to use a mechanical press which not only is unsuitable as a whole for the cold-forming process, but which also has to be covered by safety devices. We, in Great Britain, realized the significance of this, and have engineered hydraulic presses for the cold-forming processes, which are now being bought at a thoroughly economic cost.

Table I illustrates what has been done. It will be seen that press tonnages of 150, 250, 350, 500, 700, and 1,000 tons are required. It will also be seen that the costs of the conventional presses, both hydraulic and mechanical, are shown. These are typical examples of what can be purchased on the British market.

The chart shows that five firms have been approached to design a press which consists of an anvil with two vertical members, and a bridge piece with a piston in it driven up and down by a hydraulic pumping unit. The prices of all the types of presses in manufacturers' columns are shown, and it is apparent that the least cost for each type of press will be the one for which all manufacturers will ultimately have to make their presses. It will be noticed that a conventional hydraulic press of 1,000 tons would cost in Great Britain £40,000. The mechanical press would cost £16,000. The new hydraulic press of 1,000 tons can now be purchased for £7,700, which immediately makes the process of cold forming an economic proposition. In deciding the issues and the costs involved, and the final costs of these presses, it was realized that speed, when using hydraulics, does increase the capital cost, so it was decided that the normal ten inches per second which was used as a figure for cold forming should be tried out to see whether these high speeds were necessary.

It was found that $\frac{1}{8}$ in. per second in the majority of cases worked just as well, and in some cases much more satisfactorily than 10 in. per second, so that these prices are for a speed of $\frac{1}{8}$ in. per second. Should an increased speed on this be required, all that is necessary to do is to change the pumping unit.

These machines will be the basis of all future movement into cold forming in Great Britain, and there is no doubt that they will set the pattern for the rest of the world.

Having decided the right types of press to use, the next problem to resolve is that of preforms and pellet, and solid or hollow billet manufacture. In dealing with regular forms, the preforms are not of a serious nature, except in the case of the preform that requires a hole through it. The question in this case is whether it is cheaper to put the hole in with two or three low-tonnage operations, or whether it can be made in a more basic way, as a hollow billet In Great Britain at the present time the only effective hollow billet industry which supplies the hollow billet for the tube mills, machines the billet out of solid bar and so wastes the material which comes from the hole. We are inclined to think that the low-tonnage press will come much cheaper than the normal hollow billet method. Work is being done for this to be resolved.

In any case, the hollow billet must begin its life as a bar of steel, and, like the pellet and solid billet, will have the same problems to contend with. The steel trade of the world which produces bar, has, as a whole had very little fundamental work done on its plant and on the accuracy of its finished products. The bar delivered to industry from the bar mill is still a rough bar, not very accurate in size and with quite a large number of surface cracks, etc.

In cold working into mating dies the billet must be in volume as good as a commercial manufacture will allow, because to squeeze metal to waste not

TABLE I

Tonnage	Messrs. A.	Messrs. B.	Messrs. C.	Messrs. D.	Messrs. E.	Conventional Presses Hydraulic	Conventional Presses Mechanical
150	£3,160	—	£4,591	£3,593	—	£8,400	£4,700
250	£4,398	—	£4,827	£4,500	£4,125	£12,000	£5,700
350	£5,262	£6,204	£5,530	—	—	£14,000	£9,000
500	£7,044	—	£5,747	£6,386	£6,613	£16,000	£10,000
700	£10,364	—	£6,825	£7,730	—	£22,000	£12,000
1,000	£14,140	—	£7,700	£9,020	£9,950	£40,000	£16,000

Fig. 6 (above).—Differential pinion: This component is now machined out of bar on automatics, and the photograph shows a prototype of the cold-worked component, and is not yet fully worked out. This component, when finalized, will initiate the possibility of cold working the teeth into Fig. 5. Billet, 1.125 in. long × 1.5 in. dia. Concentric hole, 0.6875 in. dia. Finished dia. over all teeth, 1.875 in. Material saving over hot forging, 6½ oz. per component

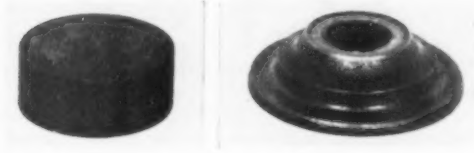


Fig. 7 (left).—Valve-spring cup: This component is now machined out of bar on automatics, and the photograph shows the pellet and the final cold-formed component, which will be produced from the pellet in three operations which are not shown, and is the only component being produced on a mechanical press which is manufactured by May-Pressenbau. It was decided to use a mechanical press because at the time it was thought that this would allow production to be initiated much more quickly. This has turned out to be thoroughly erroneous. When work on this component was first started by the British Motor Corporation, no work had been done in the world, so far as was known, in producing this type of component by cold forming. In fact, the cold heading machine trade would not undertake the work when we requested. The valve-spring cup now produced on the normal horizontal cold-heading machine is a very inferior article to the one shown. The problem with the valve spring cup lies in the making of the pellet, because it has a very short length, which produces considerable difficulties if cropping off is used. Billet, 0.365 in. long × 0.905 in. dia. Finished max. dia., 1.25 in. Material saving over hot forging, 0.116 oz. per component

only costs money in waste material, but also in producing the tonnage to do it. It has been decided therefore, not to try and reorganize the steel industry but to accept the normal end product of the steel mill and use it as efficiently as possible. This means that nearly all bar that is used for cold forming must have the diameter machined so that all surface cracks are removed and so that there can be good control over the volume of metal that is to be put into the cold-forming die. The parting off of the billet or pellet is a problem not very technical but a problem of economics. A billet which may be of a fairly large diameter with a very short length, if it was parted off with a saw or parting-off tool, could quite easily have a big proportion of waste to its finished volume. A much larger billet with a large ratio of length to diameter would have its parting off waste of a very small ratio to its finished volume. The shearing off of the pellet or billet in a cropping machine, which will help to eliminate waste material, involves certain additional press operations over and above those which are normally required in order to re-shape pellets or billets. In the case of the pellet with a short length ratio to the diameter, this is particularly vulnerable in this respect.

The machine-tool industry of Great Britain was approached to make a billet 1½ in. diameter and 3½ in. long, and a quote was put in for about £8,000 for capital equipment to do this job. It was realized that the amortization of this would not be at all satisfactory in producing the billet, so further efforts were made to use an old capstan lathe by adding bar feed and a sequence control unit to make the capstan automatic. This was done for £1,000 and has proved thoroughly economic. It is important to realize that not only the actual cold forming operations must be economic in every way, but that the making of the billet and all ancillary operations must also be engineered so that the economics are not detrimental to the final costs of the component.

In the making of the pellet, solid and hollow billets and preforms it is necessary for the production engineer to produce an economic piece of capital equipment to do this operation and, particularly, a piece of equipment that can be put into line flow and not as is done at the present time, a common installation with much "carrying to and from." The irregular-shaped component requires a large amount of work to be done on the preforms. It is very necessary to adopt a way of manufacture particularly away from the hot-forging technique, where the metal that is not required is squeezed out sideways and then clipped off. Any irregular-shaped component with excess metal at any one point causes the press tonnage to be increased very considerably if the metal has to be turned at right-angles to the squeeze between the two opposing die surfaces.

In all cold-forming operations it is necessary to use a lubricated surface on all the preforms that are put into the tools. With this lubricated surface, as with the die steels and with the fundamental steels that are used for the components themselves, nothing new need be asked for. As experience is obtained all these three may, but not

Fig. 8.—1st-speed wheel: This shows a hollow billet and the final form of this component, which is produced in one operation from the hollow billet, the manufacture of which has again to be resolved. This cold-formed component is in its experimental stage, and if adopted, would make four finished components with a saving of one pound of metal per component, besides saving the roughing operations on the machine-shop floor. Billet, 2.8125 in. long × 4.25 in. dia. Concentric hole, 2.5 in. dia. Finished dia. over all teeth, 3.75 in. Material saving over hot forging, 1 lb. per component

necessarily, be improved, but there seems no fundamental problem in either at the present time. For the lubrication process, a plant is used whereby the preforms are degreased in an alkaline medium, hot- and cold-water rinsed, phosphated, cold-water rinsed, acid pickled, cold- and hot-water rinsed, and then has a lubricated surface added finally. The author's company is using a soap surface, the trade name of which is "Bonderlube," and at present this seems most satisfactory. The plant for the application of this lubricated surface is at the present time somewhat of a crude nature, and work needs to be done on this in order to be able to engineer a plant that can be used in an inter-operational manner.

Annealing, which is another inter-operational process, is required when deformation has reached a certain limit. Annealing to-day in the mass-production industry is done by the use of large furnaces which are bulk-fed, and which results in the subsequent machine-shop plant having to accept improperly annealed components with very dire results on the tooling usage. Inter-operational annealing again wants cheap capital equipment which can be put into line-flow. This is at the initial stage of development in the United Kingdom, and it is hoped that before long the pattern will have crystallized into what the future type will be.

Among the steels used in the United Kingdom for general forged component use, by far the greatest portion, it appears, can be used without any problems. It is not quite certain yet whether certain inclusions and variants normally produced by the steel industry will produce problems or not. The use of lower-grade steels, by taking advantage of the work-hardening produced by cold forming, is something which, by producing a saving in the machine shop, can contribute to the economics of cold-forming, but are not, in the early days, a fundamental economy, but could easily be of a considerable nature.

The die steels that are used are the normal ones which have been developed in the United Kingdom, and can be purchased on the open market.

A considerable amount of surprise has been expressed from time to time at the die life obtained with cold forming. Whereas thousands of components are obtained from a die in the hot forge, tens of thousands of components can be produced from a die during cold forming. Certain users are talking of hundreds of thousands of components for die life. In fact, generally speaking, if the lubricated surface remains intact during the cold-working process, die wear will be negligible. It does seem that the constant expansion of the die during the process of pushing the steel into it will produce fatigue and then cracks. The shrink rings should always keep the die in position and, providing the crack produces a mark on the component where it does not matter, the die can continue to be used.

The British Motor Corporation do not intend to change the whole of the machine shop through the cold-forming process. There is all the machinery *in situ* to make a component from a rough forging, and while it is insisted that the cold-forming process shall be economic in relation to the hot forging, savings will, of course, be made on the machine-shop floor to a very considerable extent. It is also expected that it will be possible to take out of the machine shop all the metal-removing operations, leaving in only those operations which will be sizing and finishing. In place of these metal-removing operations there is no reason whatsoever why all regular-shaped components should not be removed from the hot forge and have the cold-working process installed into the machine shop at the beginning of each producing line. The capital equipment is now of sufficient economic cost that independent plant for each component can be used and installed in line flow.

As the problems of the irregular-shaped component are resolved, these also will be moved into the

machine shop and the hot forge, as such, will be left with the manufacture of the small quantity large components for which cold forming will be impracticable.

Figs. 1 to 8 show examples of components that have been developed by cold forming, and are being put into production by the British Motor Corporation. The photographs show the present hot forging, the billet, the cold-formed preforms, and the finished cold-formed component and the finished machined component.

It will be seen that cold forming of steels is a perfectly practical proposition and can be engineered to be a thoroughly economic comparison with hot-forging. The potential savings in using cheaper grade material, and the enormous saving in the machine shop are such that no production engineer can afford to ignore these potentialities and refrain from making the fullest use of experiments and development work to use the process in a practical way.

DISCUSSION
of the two foregoing papers

Mr. L. R. HAWTIN (I.C.I. Metals) said that there was a conflict between Mr. Griffiths and other lecturers on the matter of tools. It was apparent from Mr. Morgan's paper that considerable care was needed in the making of these. Very close tolerance was required and also care in design. It also appeared, from papers yet to be presented, that great care was also needed in the heat treatment and finishing of the tools. This seemed difficult to reconcile with Mr. Griffith's comment that the tools should cost no more than hot forging tools.

Mr. GRIFFITHS said that in the paper, and in his later remarks, he had emphasized that an attempt was being made to get accurate basic components that could be finish-machined. It was a different problem when one made an irregularly shaped die, with the massive marking out, milling, filing, etc., that was involved ; the ordinary, regularly shaped die was cheap to make.

Analyzing Production Cost

Mr. MORGAN (R.O.F.) said that his own organization had made an analysis of the cost of producing a particular component. Mr. Ketchin who had done the work estimated that the cost would be 5s. 10d. when produced totally by cold forming. A suggestion was made that the production cost might be reduced if a machining operation was substituted for two of the cold-forming operations, with a slight additional waste of material. At first thought it appeared that this suggestion might well result in quite a satisfactory reduction in production cost but in the ultimate it was found that this proposal would cost 6d. more than the fully cold-formed component. It might be inferred from this analysis that his organization was inefficient in its machining costs but, of course, the efficiency of any organization often depended very largely upon its capital investment and, of course also, the type of work it was set up to produce. To illustrate this point further ; in another case a large organization had asked them to consider the mass production of a component by cold extrusion which was currently being produced by machining two separate components each of which had a screwed end by which they were joined together. As a first guide an estimate was made as to the current manufacturing costs ; then an estimate of the cold-extrusion costs was made and the price of 3s. 3d. appeared to be within the machining cost. It turned out, however, that the firm were far more efficient in their machining techniques than was thought possible and they were currently machining both components for 2s. 3d. It was clear, therefore, that in order to be competitive the cold-extruded components had to be produced for 1s. 9d. approximately so as to permit an amortization of the capital investment which would be required in setting up the cold-extrusion plant line. It is possible that the amortization costs for cold extrusion could be substantially more than for machining a component, and this point had to be well borne in mind.

Mr. J. F. KAISER (Gillette Industries Ltd.) said that he had listened with great care to everything that had been said, and had also read the papers carefully. He wondered whether he was correct in assuming that Mr. Griffiths meant what he said in his paper. On page 1 he had referred to the symposium held in 1953 and had suggested that, technically, it had been much too advanced for British industry. He would only comment that it was a sad reflection on British industry if it was unable to absorb the papers. In fact, if this was true then he presumed that Mr. Morgan's paper also would fall on stony ground.

It was said in the paper that the finish of the tools should be such that scratches could not be seen with the naked eye. One might just as well say, "I want a hole through there—fairly big." For the last 20 years it had been possible to measure surface finish. Surely the time had come when the surface required should be on every drawing of a tool ?

On pp. 4 and 5 Mr. Griffiths had referred to cracked bars. There was only one place for cracked bars and that was back with the supplier. Did he

really mean it when he said that the mild steel received in comparatively small sizes—1, 2 and 3-in. round—was full of cracked surfaces?

On p. 6 he referred to mass-production annealing in large furnaces as being something of a hotch-potch. Mr. Kayser had only been engaged, personally, in mass production for 28 years, but when he had joined his first mass-production firm that sort of thing was no longer being practiced.

The impression gained from the paper—he wondered whether this was what the author intended—was that his organization proposed making cold-extruded parts from low-grade steel on second-hand presses.

Mr. GRIFFITHS said that he had not spoken of using second-hand presses for production, though, as far as he was concerned, cast iron and steel did not deteriorate in capital equipment; it was quite easy to take cast iron that was 50 years old and bring it up to the same degree of accuracy as the most modern piece of capital equipment by various means. His point had been that industry had to be recapitalized but that it should be done at the right price.

Use of Low-grade Steel

So far as low-grade steel was concerned, in the consumer industries steel from 20-tons yield point to 90-tons yield point was used, with the price difference ranging from £60 to £100 per ton. The component with a large flange and bosses, which was shown outside the conference hall, was made as a hot forging from a very high grade 70-ton steel which produced almost impossible machining conditions on the shop floor. It was necessary to put a large quantity of machinery in to cope with it. If 30-ton steel was used, which was low grade in terms of tensile strength, the work-hardening properties could be used to give it exactly the required physical properties using the cold-extrusion process. In fact, these proved superior to those obtained from the other steel. The term "low-grade" referred to the tensile strength.

In regard to the cracks in black bar, as Mr. Okell had said so clearly, the steel industry as a whole in the bar field, had not yet rationalized its production to the same extent as had the sheet producers. The latter were producing a very accurate piece of material. His organization was not going to make inroads into cold forming by trying to use the steel as it came out of the mill. They were machining to make sure that there were no surface defects in it at all. They could afford to do so because their amortization costs were very low; they could afford these extra operations.

Batch annealing was a problem facing the whole of the mass-producing industries. There was not a machine shop in the country that would not complain about the standard of the components coming from the hot forge. The problems of tool maintenance, tool life and tool wear and tear that were caused by improper annealing were tremendous. The point that he had been trying to make in his paper was that the large batch furnace was the one used in industry. It had a 4-ft. × 3-ft. or 2-ft. × 2-ft. hole into which material was fed in bulk. The material was fed through in different sizes with differing contents, shapes of components, holes and so on. The man trying to do the annealing was everlastingly playing about with his temperature range in order to try and find the right level. The end result was an imperfectly heat-treated object. It was important to put annealing and heat treatment in the line, the same as any other operation. The particular piece of capital plant should be engineered and maintained to a standard which repeated itself all the time, and would not be affected by differences in volume.

He had suggested that the papers delivered at the 1953 conference were in advance of British industry because in those early days he had sent drawings to dozens of people asking them to produce them by cold forming, but a reply had only been received from Mr. Morgan's organization. Private enterprise simply was not ready then and had not since helped cold forming as a process to any extent worth mentioning. The main work had emanated from N.E.L. and especially R.O.F. The latter had done more than any other organization in the country to help it along.

Mr. J. D. MANTLE (Ministry of Aviation) asked whether the impressive savings on tools which Mr. Griffiths had quoted, meant that one could expect a reduction of £100 in the cost of B.M.C. cars in 1963/64? More seriously, he had said that only two things were of importance—the preformed stage and the pressure required—that speed of forming was of no consequence. For mild steels one could accept this, but later Mr. Griffiths had said that for some of his components he had used a lower grade steel and got his results from work-hardening. Surely then the speed of extrusion was of vital importance? It was not possible to have it both ways. In that respect, if he was getting improvement from his steel through work-hardening surely the improvement depended upon the working, which differed in various parts? Was he quite happy from the design aspect that his resulting component was going to be efficient?

Speed of Cold Forming

Mr. GRIFFITHS said that it was necessary to be careful not to confuse the speed of cold hobbing with the speed of cold forming. What he had said was that $\frac{1}{8}$ in. per sec. which was reasonably fast, was quite as good in doing the job as 10 in. per sec.

It was the range of speed which suited the company's output, and the work-hardening properties seemed to be perfectly satisfactory. This was the result on test. However "long-haired" one might be about results "on test" they could not be denied.

His terms of reference as the chief development engineer of B.M.C. were to keep the cost of the cars at par. Increases in other directions were so pressing that it was a tremendous task to do this.

Mr. R. H. SPIKES (Joseph Lucas Ltd.) said that in his cost figures for hydraulic presses, Mr. Griffiths was working basically on his low production of one component a minute or so. People in the lighter branches of industry who supplied B.M.C. and other branches also, were interested very often in making 50,000 components a week rather than 5,000 and did need higher speeds of operation. Had the author considered the extra costs of the larger pumps and other hydraulic equipment, and did he still consider that the hydraulic press was preferable to the mechanical press?

As regards the lubrication process described on page 6 of the paper, if he pickled after he phosphated, he would find difficulty in extruding.

Mr. GRIFFITHS said that though the hydraulic press gave greater flexibility in this process the enormous cost of the equipment made it essential to consider the mechanical method. He had himself investigated the matter, but the salesman who had come to see him—after doing his best to sell him the mechanical press—had settled back in his chair and proceeded to "flatten" him with a description of all the gadgetry which it was necessary to put on to prevent it from doing this, that, and the other over dead centre, as well as safety devices, etc. An hydraulic press required no safety devices other than that of keeping the operative away. It came straight down on to the top of the die and was, therefore, more satisfactory, if it could be engineered at the right price.

On mass production he would only say that the mechanical press might be acceptable from the point of view of capital cost in a particular industry, but it was possible to work the hydraulic press at very high speeds also. The 1,000-ton press which his company were buying was costing £7,700 and was based on a speed of $\frac{1}{4}$ in. per sec. but it would cost only £1,000 to alter so as to run at 10 in. per sec. For high-speed productivity the increased cost of the capital equipment would not vary in any other way. It was only a matter of going up and down with a very short stroke very quickly, and then putting in some sort of automation. He believed in putting the cost of all the gadgety, not in a piece of capital equipment, but in the tool because this was a maintenance cost.

Mr. MORGAN said that it might be of interest to mention that it was not necessary to have a very expensive hydraulic or mechanical press; it was possible to extrude on a very simple tup press. R.O.F., for example, had a very old-fashioned tup press for billet breaking. Mr. Ketchin had made a small die and had produced a perfect extrusion—so much so that the base thickness was nil; everything had gone up in the walls.

Punch Stress

Mr. H. Ll. D. PUGH (National Engineering Laboratory) said that on p. 3 of his paper, Mr. Morgan had referred to the punch stress as generally being of the order of 120 tons per sq. in. He would suggest that this was the hydrostatic component stress which should be applied to the die wall. He would like to differ from Mr. Morgan in the sense that if it was possible to relieve the extrusion pressure the stress of 120 tons could be considerably reduced.

In the United States, Thompson had attempted to measure the pressure on the wall. He had found that it was about 90 per cent of the extrusion pressure. This would suggest that the pressure to be applied to the die wall should be less than the extrusion pressure which, in turn, was considerably less than the punch pressure of 120 tons per sq. in. This was also borne out if a theoretical problem of indentation—after all a canning problem was essentially an indentation problem—and a two-dimensional solution, were considered when it would be found that the stress on the wall was considerably less than that of the punch.

On page 4 reference was made to the fact that it had been ascertained that for normal cold extrusion of steel the best design of die was that in which the K ratio of the radius of the outside diameter of each of the shrink rings with the radius "R_z" of the die bore was the same—1.6. On what grounds did Mr. Morgan make this statement? Was it on experimental investigation? There was reason to believe that the best design might differ considerably from this. The same K ratio did not apply for every ring and it would be very different from 1.6 anyway.

His reason for saying this was that in almost an identical problem of pressure vessel design, with 650 tons per sq. in., the K ratios had been considerably different. Also, the solution given did not seem to be real, in the sense that having fixed upon a K ratio of 1.6 he then calculated what the shrinkage would be. It was possible to obtain the design of die by fixing the appropriate interference.

Calculation of Stress System

The general calculation of the stress system in the rings was based on an elastic analysis and he would make a plea that in the design of containers to stand

very high stresses an elastic/plastic analysis should be used. To illustrate his point: there was nowhere in the design a statement of the yield criterion of the materials. Mr. Morgan had quoted a failure criterion but not a yield criterion. In Figs. 9 and 10, radial compressive stress due to extrusion load of 120 tons per sq. in. was shown and tensile stress of 63. The stress difference worked out at 180 tons per sq. in. The steel, to remain elastic, would need a yield strength of 180 tons per sq. in. Clearly it would not do so on Mr. Morgan's assumption of a yield strength of 60 tons. The net effect was to produce a plastic region around the bore. He had not himself checked the figures but he suspected that it would be obtained in other places too. This particular region would not sustain a stress of more than, say, 60 tons, throwing a higher stress on the other parts of the container. In other words, the stress allowances for the container would be considerably different from those shown.

In designing containers it was necessary to consider the possibility—it was no more than a possibility—of plastic deformation occurring as a result of shrinkage alone, and without putting on any internal pressure. It was conceivable that it would be possible to put so much pressure on as to make some of the faces plastic.

Mr. MORGAN replied that his organization had at least stressed a set of cold-extrusion dies, and no-one else had. He would like to see Mr. Pugh's "stressing" and go through the calculations for half an hour before debating it on the platform.

Mr. PUGH said that a paper by M. R. Horn given to the Institution of Mechanical Engineers some six years ago had described a plastic analysis of thick cylinders and multi-ring containers generally.

Mr. MORGAN said that the method which he had described in his paper was that used in the R.O.F. for designing all their cold-extrusion dies. It was simple to remember and it was effective. In the early days on this work various dies had fractured but he knew of no such case since the method described had been established.

So far as the question of the load of extrusion was concerned, an indicator reading was taken of the actual tonnage being used in extrusion. The readings made it fairly clear that the pressure being exerted was about 120 tons per sq. in. He was bound to admit that it was wrong to say that the punch extrusion pressure of 120 tons per sq. in. was also the radial hydrostatic stress on the inner wall of the die. From later analyses it seemed clear that as soon as the formation of the component commenced it became itself an integral part of the die in resisting hoop stress. If the measurements of the actual components which were quoted in the paper were analyzed it would be seen that the outside diameter was much less than would have been the case had a radial pressure of 120 tons per sq. in. been applied at the die bore. It appeared to be about half of it. The application of extrusion pressure causes both the punch and the die to expand and the component which is produced has a temperature of about 150 C. Working backwards from the size of the component produced, and taking account of all facts, it appeared that the radial stress on the die bore would be about 70 rather than 120 tons per sq. in. and, therefore, there appeared to be ample safety factor. However, from the production point of view it was always necessary to put in a die with ample safety factor which would then take into account those badly annealed billets to which Mr. Griffiths had referred. In the mass-production annealing of billets it seemed clear that they would not all be perfectly annealed and some would remain rather hard, so that plenty of safety factor was required.

Mr. R. E. OKELL said that there seemed to be two widely separated approaches to the question of cold forming. The first was to get a hydraulic press that was relatively cheap or worn out and rebuild it by empirical means, forming the part in the knowledge that it was not possible to break the press. The second was to obtain the knowledge by some method or another and then put in new presses, in which case most people would adopt the mechanical type. Would the two authors comment on the two methods of approach?

Die Costs

While he was on the subject he would mention the question of die costs. The impression given was that if accurate extrusions were not required the die costs would be very low because the die need not be accurate, but there remained all the clearance fits and drive fits to give the right stress system in the tools themselves. These would not be altered as far as he could see by the accuracy of the component, and this would be something like 97 per cent of the accuracy of the work.

He would like also to refer to the mechanics of component production. The labour factor had more or less been eliminated and thus one was left with the steel. Steel cost 6d. a pound and it was possible to spread a pound of steel a very long way on machining allowances. The modern drop hammer produced steel components very rapidly but starting with perhaps three times the capital cost of the proposed hydraulic extrusion press, but the production itself took place at many times the rate of that from hydraulic presses. If they were not careful they would be chasing far too little steel and putting far too much work into it, the net effect being a loss rather than a gain.

He would like to question the suggested cost of

turning the rather impractical $\frac{1}{4}$ in. per sec. speed into the more practical production speed of 10 in. per sec. If one kept the $\frac{1}{4}$ in. per sec. speed, or even three times that figure, did one put several of them in a row and have one man load the lot? This would simply mean increasing the capital outlay for the same result. From Mr. Morgan's question of the previous day he must assume that he used black bar. If so, he would repeat that question: Did he think the black bar was up to the standard he desired?

Use of En2E Steel

Mr. MORGAN said that in the armament field it was not customary to use black bar. They used instead a bright-drawn En2E steel. He was not, however, satisfied with the quality which varied considerably and this gave continuous trouble. One job which his factory was currently engaged on required that the head of the component be slightly expanded in a tapered form. This operation was very successfully performed with reasonable quality steel but it was not unusual to receive a cast of dirty steel, and splits then occurred on the outside diameter. In normal everyday life it was not practicable to examine every delivery of steel bar for imperfections. If one paid for quality steel it was reasonable to accept the steel which was delivered on trust. If the manufacturer could not trust the steel quality it put a serious brake upon the development of cold-extrusion processes. The steelmaker might well accept the responsibility for replacement of dirty steel but in the meantime great harm had been done because of the breakdown of the production line and the increase in the manufacturing costs. In the particular job to which he referred the normal production cost of 2s. 8d. each had risen to 3s. 4d. simply because of dirty steel, and too much stress could not be given to the importance of paying more attention to the problem of manufacturing clean steel. If cold extrusion was to become a really successful process it was necessary to be able to turn out *finished* components and to eliminate subsequent machining operations. It might be advisable therefore to choose components which were expensive to machine—gear wheels for example. The normal hollow component which was relatively easy to produce by forward or backward extrusion, was also often very cheap to machine on automatic machine tools.

Mr. OKELL asked whether Mr. Morgan and Mr. Griffiths would comment on the two methods of approach.

Mr. MORGAN thought there was room for both—so much depended upon the product which was to be made and the quantity required. It was quite possible to enter the cold extrusion field enthusiastically and to become overburdened with capital cost. He had seen an armament cold-extrusion line laid down which must have cost a great deal of money. Nevertheless, it was capable of turning out many thousands of fully finished armament products each week and was therefore a very economic unit. Each producer therefore had to make up his own mind as to what was best for him. Normally, hydraulic presses were costly items, but certainly press manufacturers were going out of their way to reduce their costs very substantially and were entering the cold-extrusion field realistically. Mechanical presses were also fairly expensive and, of course, had certain physical limitations.

Mr. GRIFFITHS felt that it was necessary always to advocate the hydraulic press, only using the mechanical press for very special components. The hydraulic press, as he had said before, was almost unbreakable. It was possible to bring it straight down on to the die without the need for safety devices other than that for the operator. With the mechanical press there was a "dead centre" and all sorts of other things to worry about. He intended to advocate the hydraulic press which had been engineered for the process and hoped that his company's suppliers would be able, as a result, to buy properly priced capital equipment in order to give B.M.C. its components at the right price.

On die accuracy, apart from the shape, it was straightforward toolroom practice. Shrink rings were everyday practice. It was not costly and he would still say that the cold forging die was a cheap piece of equipment and the user should not be afraid of replacing it quite often. It would certainly not be replaced as quickly as the die used in hot forging.

In regard to the economics of producing the component, the paper had given the actual metal savings and had pointed out clearly that metal was left on for subsequent machine finish operations. The metal saving was not at all chancy; it was considerable, amounting to probably 1s. 3d. or more of the material that was normally used in the hot forging process.

Mr. MCKENZIE (N.E.L.) said that Mr. Morgan, on page 2 of his paper, had said that the extrusion load for a backward extrusion as in his Fig. 1 was normally some 20 per cent lighter than for the other methods. His own experience was that a rod extrusion and a tube extrusion—a Hooker extrusion—required exactly the same extrusion stress. In can extrusion it was something like 40 per cent lower extrusion pressure.

If a billet of a specific diameter was extruded either by the method in Fig. 1 into a can, or the method in Fig. 2 into a rod, the extrusion load for the rod would be some 10 per cent higher than the extrusion load for the can, the reductions being exactly the same. What did Mr. Morgan mean by

(Continued in page 134)

ISME Discussion

(*Continued from page* 133)

"20 per cent higher"? and would he clear up the doubt raised by his continual reference to 120 tons per sq. in. stress? His own experience was that in a can extrusion the minimum pressure for a specific material occurred around 50 per cent reduction, and when extruding either at a higher or lower reduction the pressure was somewhat higher. Comparing the stress on the die face and rod it was found that the stresses were somewhat higher than on the punch.

Mr. MORGAN said that he did not think Mr. McKenzie had quite completed his last statement. He had doubted the figure of 120 tons per sq. in. on the punch and had said that his experience showed that about 50 per cent cross-sectional area reduction gave about the minimum load on the punch, but had not said what load on the punch he expected to get.

Mr. MCKENZIE said he was speaking, not about load but about pressure; the load would be less with lower reduction. It was stress that would increase on the punch.

Mr. MORGAN suggested taking the total load from the press and dividing it by the cross-sectional area. What did Mr. McKenzie get?

Mr. MCKENZIE said that for 120 tons the steel would be something like 0.08 carbon content or less, and it was his experience with an En2E that the stress on the punch was nearer 135 tons per sq. in. minimum at 50 per cent reduction.

Mr. MORGAN said that the R.O.F. had had varying results between 120 and 135 tons per sq. in. stress on the punch at 50 per cent cross-sectional area reduction on En2E steel. The figures quoted were obtained by dividing the total load given by the press by the cross-sectional area of the punch, so apparently the R.O.F. and N.E.L. were on a common basis there. Initially they had thought that this punch stress would be translated into a similar intensity of hydrostatic radial pressure on to the die walls. They had made this assumption because the material being extruded had, in fact, become plastic. It was now felt that this assumption was incorrect and dimensional examination of extruded components showed this to be so. The intensity of radial pressure on the die walls was something much less than 120 tons per sq. in.

In speaking of the extrusion load being "20 per cent higher" he was speaking of cans produced by forward and backward extrusion. In other words, the load as in Fig. 1 would probably be 20 per cent higher than in Fig. 4.

Mr. MCKENZIE said that from Fig. 4 it would appear that the die had actually a reduction in it as well. Was this correct?

Mr. MORGAN said that it probably had. It had not been mentioned. If it was assumed that the same component exactly was being made in each case—a straight can with straight external walls made by backward and forward extrusion—there would be less loading in the forward extrusion (Fig. 4) than in Fig. 1.

Mr. MCKENZIE disagreeing, said that whether the can was forward or backward extruded, if the taper was as in Fig. 4—and there was no reduction in the die, which was dead parallel all the way down—the loads would be comparable. The percentage difference was of the order of ± 2 per cent which was well within experimental accuracy. He still thought that Mr. Morgan was not answering the question concerning the statement that Fig. 1 gave 20 per cent higher load than for other methods, which would include Fig. 2.

Mr. MORGAN replied that it was, perhaps, rather loosely phrased. As had been explained, the comparison was between Fig. 1 and Fig. 4.

Mr. MCKENZIE said that in his experience it was 15 per cent lower.

MR. MORGAN disagreed.

GAUGE AND TOOL MAKERS' ASSOCIATION

Members to Visit Moscow

FORTY-EIGHT directors of firms in the Gauge and Tool Makers' Association will be taking part in a group visit to Moscow which the Association is organizing during the forthcoming British Trade Fair in that City. (May 19 to June 4, 1961.)

The group will leave London Airport by a British European Airways Comet Special Service flight early on Saturday, May 27, returning by a similar flight on Wednesday evening, May 31.

LIGHT-METALS CONFERENCE

THE Fourth International Light Metals Conference will be held in Leoben from June 20 to 24, 1961. The main theme of the Conference will be "Light Metals in Light Construction, in Architecture and in Special Fields" and a large number of papers, and social events and works visits have been planned including a visit to the Austrian Aluminium Works. One of the papers is being contributed by Mr. R. M. Davies, the structural engineer of the Aluminium Development Association. Enquiries concerning the Conference should be addressed:

Geschäftsstelle der 4. Internationalen Leichtmetalltagung Leoben/Stmk., Montanistische Hochschule, ÖSTERREICH.

An Introduction to the

THEORY AND PRACTICE OF FLAT ROLLING—6

By the late C. W. STARLING, B.Eng., A.M.I.Mech.E.

(*Continued from page 55, January, 1961 issue*)

THE EFFECT OF MILL SPRING ON GAUGE

FOR all practical purposes it has been shown that the load spring relationship for a given mill is a fixed straight line, if the toe of the curve is ignored. This can be seen from Fig. 108, which shows a typical load spring curve for a 4-high cold mill. If the load spring curve is taken to be a straight line, the slope of the line being constant for any given mill, this slope is defined as the *mill modulus* for that particular mill. This modulus is in tons per inch units and will be the hypothetical load which would be required to cause a mill spring of 1 in., assuming that this was possible with the mill still behaving elastically. The modulus for any given mill can, therefore, be obtained by plotting the load spring relationship and drawing the mean straight line over the normal working range, the slope then being measured directly.

If there was no "toe" to the curve and this mean straight line passed through the zero point, the complete relationship between the load and the spring would be known from the mill modulus. In actual fact, however, the straight line will cut the x axis at some point, say S_o and the mill spring will then be S_o plus the spring obtained from the modulus. That is, Spring $= S_o + \frac{F}{M}$, as seen from Fig. 109.

Taking this further, much more information can be obtained if the initial roll setting is introduced into the modulus curve. If there is an initial roll gap of S, the modulus curve will start at S instead of zero, as shown in Fig. 110. A family of such curves can then be obtained for any given mill for various roll settings, and the finished gauge for any roll setting and rolling load can be obtained directly from this family of curves. In practice, it is more convenient to be able to calculate gauge

Fig. 108.—Typical load/spring curve for a small 4-high mill

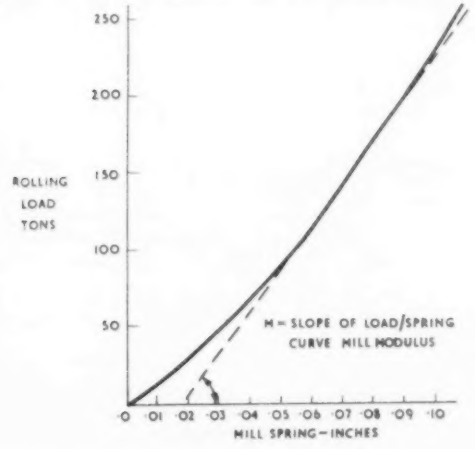
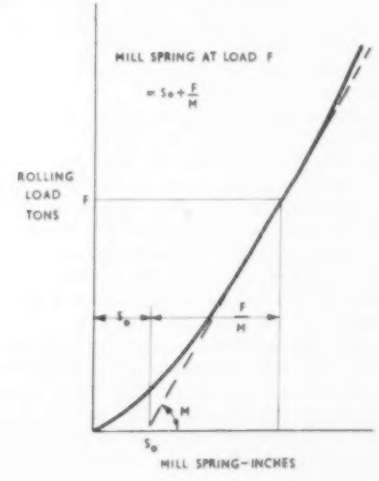
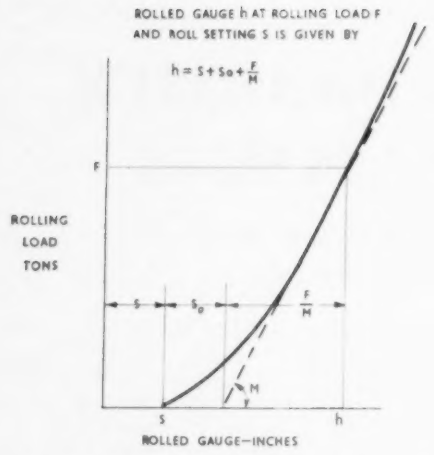


Fig. 109.—Curve showing how mill spring is calculated from the mill modulus





directly without drawing the family of curves and for this it is necessary to know the values of S_o and M for the mill in question.

If mill spring is $S_o + \frac{F}{M}$ and the roll-gap setting is S,

then finished gauge $h = S + S_o + \frac{F}{M}$ . . . . . (26)

where F is the rolling load.

Use of Equation 26 to obtain the finished gauge will give reasonably accurate results, but in practice there are several factors which influence its accuracy.

(1) It has already been shown that the equation is based on a linear relationship between load and spring, whereas in practice it is known that there is a slight curvature. Normally a mill works over a restricted load range and the error due to curvature of the graph will be small, provided that the value of M for this small range is used. It may be different from the mean value of M for the whole range, as seen from Fig. 111.

(2) It will be affected by the temperature of the rolls and the mill. When a mill starts up from cold, the rolls heat up quickly and the housings heat up more slowly until they reach normal running temperature. It has been shown that after several hours the temperature of the mill becomes fairly constant, but the roll temperature fluctuates considerably with the rolling schedule and rolling speed. It will be obvious that when a roll heats up, its diameter increases and for a fixed screw setting this reduces the roll gap S. If this roll gap was measured directly this would not be important, but in practice it is usual to measure the gap from the screw position and a change in diameter of the roll will, therefore, effect the roll gap. Similarly, when the housing is warming up it will expand slightly, allowing the roll gap to increase for a given screw setting.

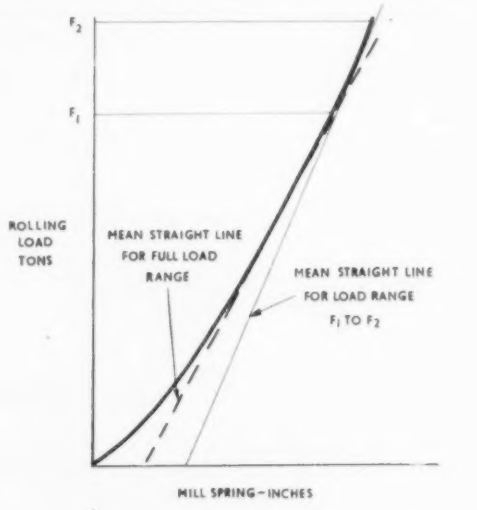
(3) A further source of error is eccentricity between the back-up roll neck and barrel and any ovality of the rolls. If the rolls are oval it is obvious that there will be a cyclical variation in the roll gap, the frequency of the cycle and the amplitude depending on the relative position of the oval rolls to each other. The eccentricity of the back-up roll barrel referred to the roll neck which is running in the bearing, will have exactly the same effect. Any eccentricity between the barrel and the neck of the work-rolls in a 4-high mill, however, should not have this effect, as it will be taken up by the vertical movement of the chock carrying the work-roll neck bearing in its slides.

Modulus of Rolls and Housing

It has been shown that the spring of the mill is the sum of the spring of the rolls and the spring of the housing. If, however, the load spring curve is drawn for the housing and rolls separately and the modulus obtained for each, the mill modulus will not be a direct addition of the modulus of the rolls and the modulus of the housing. A rolling mill will behave in an identical fashion to two coil springs in series, subject to external forces. Then

Fig. 110 (top left).—Curve showing how gauge is calculated from the mill modulus.

Fig. 111 (below).—Graph showing the variation in mill modulus for different load ranges



if M_h is the modulus of the housing and M_R is the modulus of the rolls, it has been shown by *Hessenberg* and *Sims* that

$$\frac{1}{M} = \frac{1}{M_h} + \frac{1}{M_R}$$

In practice, as already explained, it is relatively simple to obtain the value of M by direct measurements and it is this value which is normally used. In rolling-mill design calculations, however, it may be useful to know the relationship between the modulus of the rolls, the housing and the mill.

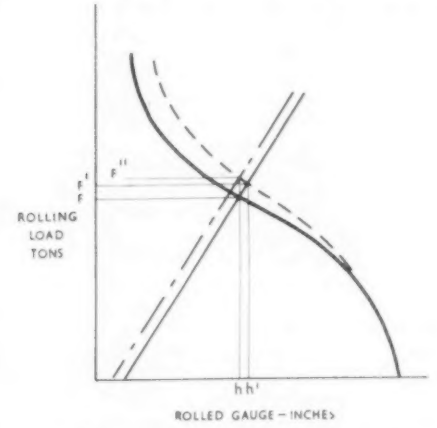
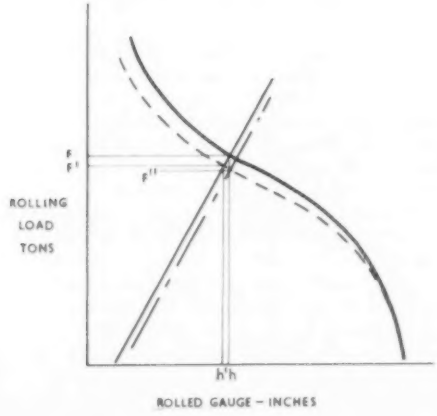


Fig. 112 (above).—Elastic/plastic curves showing the effect of an increase in friction

Fig. 113 (below).—Elastic/plastic curves showing the effect of an increase in tension

Fig. 114 (below, right).—Elastic/plastic curves showing the effect of an increase in yield stress



The Elastic/Plastic Curve

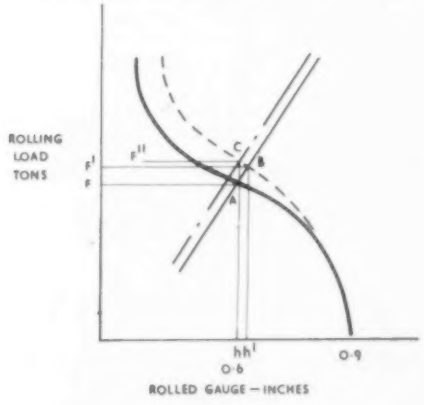
The plastic curve has already been discussed and the effect of various factors on the plastic curve has been shown by a series of graphs. The plastic curve has also been discussed at some length by *Hessenberg* and *Sims*.

The plastic curves for the material being rolled can now be plotted on the same graph as the elastic curves of the mill and from the various families of curves, a great deal of information can be obtained. A number of examples will show some of the information which can be obtained from these curves.

Fig. 112 shows the elastic and plastic curves for a given mill rolling a certain strip. If for some reason, such as a breakdown in lubrication, the coefficient of friction is increased, this will be shown by the dotted line in Fig. 112. From the original curves, at roll force F the final strip thickness was h, but for the same roll setting it will be seen that the new point of equilibrium gives a greater roll force F′ with a greater final thickness h'. The effect of an increase in friction, therefore, is to increase the roll force for a given roll setting and also to reduce the reduction obtained in the pass. If the rollerman wishes to maintain his outgoing gauge constant, he would change his roll setting by screwing down more and the new elastic curve shown by the chain dotted line will intersect the plastic curve at a new force F″ at the required outgoing thickness h. The information which can be obtained from Fig. 112 is then summarized as follows.

If the coefficient of friction increases, for a given roll setting the roll force will increase and the reduction in the pass will be reduced. If a constant outgoing thickness is required, the roll-gap setting will have to be reduced by screwing down and the roll force will be increased.

Fig. 113 shows the elastic and plastic curves for a given mill cold rolling strip under tension. The



equilibrium condition between the elastic and plastic curves for a certain front tension is shown by the full lines, with a roll force F and a rolled gauge *h*. If the tension increases at a fixed roll-gap setting, the plastic curve will move, as shown by the dotted line. The new position of equilibrium then gives a roll force F′ and a finished thickness *h*′. The effect of an increase in tension for any roll setting is, therefore, to reduce the roll force and to increase the reduction in the pass. If a constant outgoing gauge is required, the screws will have to be raised slightly, giving a new elastic curve, as shown by the chain dotted line. The roll force F″ will then give the required thickness *h*.

Fig. 114 shows the elastic and plastic curves for a hot mill rolling sheet which has a certain yield stress. If this sheet were suddenly to become harder, perhaps due to cool streaks, the new plastic curve would be as shown dotted. This will have the effect of increasing the roll force F to F′ and increasing the final gauge from *h* to *h*′ at a constant roll setting. If a constant outgoing gauge is required, the screws will have to be brought down to give the new elastic curve shown by the chain dotted line and the new roll force required will be F″.

The effect of any factor on the elastic or plastic curves can be shown qualitatively very easily by freehand sketches of the above graphs, but it is also possible to obtain the quantitative analysis provided that the curves are drawn to scale.

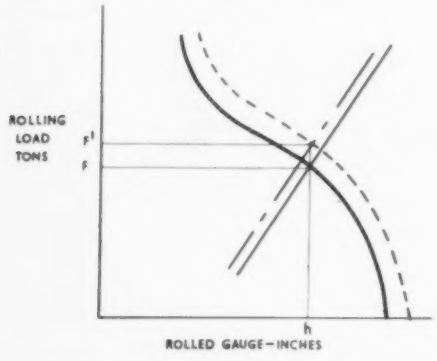
The question of setting up the individual mills of a continuous strip mill will be discussed in a later chapter, but it will be of interest here to show how the qualitative settings of the screw can be obtained from the elastic/plastic curves. Consider the case of a continuous strip mill, where slab on the delay table is 0.9 in. thick and it is reduced to 0.6 in. in the first of the finishing mill train. This can be represented by the elastic/plastic curves, as shown in Fig. 114. The position of equilibrium A, shows a thickness of 0.6 in. under a rolling load F. The next bar on the delay table may vary in several ways, the most usual variations being in width, thickness, temperature and steel grade. If, for example, the second bar is identical to the first, but cooler, the plastic curve will move, as shown by the chain dotted line in Fig. 114 and the new position of equilibrium B will be F′ with a new thickness *h*′, which is greater than 0.6 in. In order to obtain the correct gauge from this mill, the screws must be brought down, as shown by the chain dotted line in Fig. 115, with a new equilibrium position at point G.

If the second bar is wider than the preceding one, again the movement of the plastic curve will be in the same direction as for the cold bar and similar corrective movements of the screws will have to be made. Similarly, if the second bar is of a different analysis, giving a higher yield stress, there will be a similar movement of the plastic curve and again a similar correction by the screws.

If the second bar is thicker than the preceding one, the plastic curve will move bodily, as shown by the dotted line in Fig. 115, and it will remain substantially parallel to the original plastic curve. Again a correction will have to be made by screwing down, as shown by the chain dotted line in Fig. 115.

The direction of movement of the screws for any variation in the ingoing bar can be worked out along these lines, but the actual distance the screws must be moved can only be obtained by an accurate plot of these graphs and in practice this would involve a considerable amount of experimental work to plot a large number of plastic curves. In order to obtain full automatic control of a mill, this will eventually have to be done and the value of the roll-gap transfer function obtained under any rolling condition.

Fig. 115.—Elastic/plastic curves showing the effect of an increase in ingoing gauge



Roll-gap Transfer Function

Every rollerman knows in practice that if he wishes to change the gauge of a sheet by, say, 0.002 in., he will have to screw down a greater distance than this, the actual amount varying from a little more than 0.002 in. on thick hot sheet to a very high figure when the sheet is thin and hard. This is a mill spring effect and is given the technical term the *Roll-Gap Transfer Function*.

The magnitude of the roll-gap transfer function and its variation under different conditions can be examined by means of the elastic/plastic curves. Fig. 116 shows the elastic/plastic curve for a hypothetical case, where the finished gauge is *h* at a rolling load F. A is the equilibrium point. If the screws are brought down a distance $\triangle S$, the elastic line will be moved to a new position shown chain dotted in Fig. 116 and it now intersects the

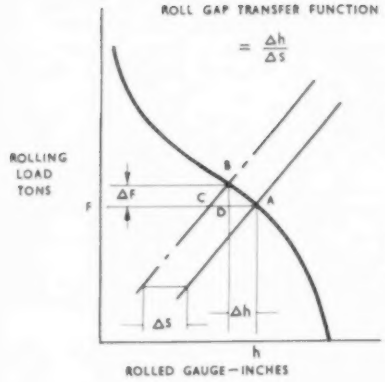
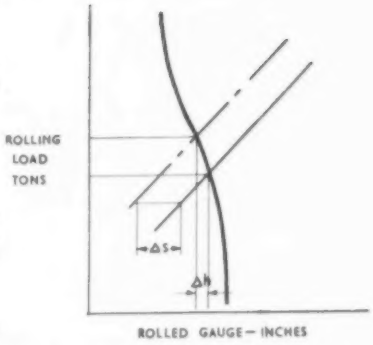


Fig. 116 (left).—Elastic/plastic curves showing the roll-gap transfer function

Fig. 117 (right).—Elastic/plastic curves showing the roll-gap transfer function for a thin hard material



plastic curve at point B. The change in roll force from A to B will be $\triangle F$. If a straight line is drawn from A to B, in practice this distance is small and the straight line will correspond very closely to the plastic curve between A and B. If Q is the slope of this line, then

$$\frac{\triangle F}{\triangle h} = Q$$

From the geometry of Fig. 116 it will be seen that $\triangle S = CD + DA$ and as M is the slope of the line CB,

$$\triangle S = \frac{\triangle F}{M} + \triangle h$$

Eliminating $\triangle F$ from the above two equations gives

$$\triangle S = \frac{Q \triangle h}{M} + \triangle h$$

$$\text{or } \frac{\triangle S}{\triangle h} = \frac{Q}{M} + 1$$

The roll-gap transfer function can be defined as the screw movement required to give a certain change in roll thickness.

Then,

Roll-gap transfer function $=$

$$\frac{\text{Change in thickness}}{\text{Movement in screw}} = \frac{\triangle h}{\triangle S}$$

Then from the above equation the roll-gap transfer function $= \frac{\triangle h}{\triangle S} = \frac{M}{M + Q}$

Taking a numerical example, if the roll-gap transfer function is $\frac{1}{5}$ it means that,

$$\frac{\triangle h}{\triangle S} = \frac{1}{5}$$

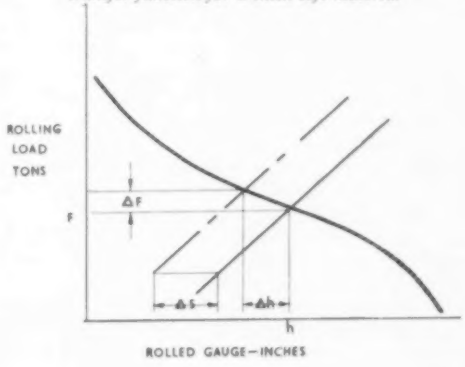
$$\text{or } \triangle S = 5 \triangle h$$

i.e. the screw movement required is five times the change in thickness required.

As every rollerman knows, on a thick, soft material the screws are only required to move a relatively small distance to make a correction in gauge, or in other words the roll-gap transfer function approaches $\frac{1}{1}$. On the other hand, when the limiting thickness condition is approaching, the screws must be moved a considerable distance to make any correction and the roll-gap transfer function begins to fall at an ever-increasing rate until the limiting thickness is reached, and however far the screws are moved there is no change in gauge. The roll-gap transfer function then becomes zero.

This effect can be seen from the elastic/plastic curve. Fig. 117 shows the plastic curve for a very thin, hard material and it is immediately obvious from this diagram that $\triangle h$ is small compared with $\triangle S$. Similarly, for a thick, soft material the plastic curve will be as shown in Fig. 118 and it will be seen from this that $\triangle h$ approaches more nearly to the value of $\triangle S$. Referring now to the equation for the roll-gap transfer function, it will be seen that for a thin, hard material giving a curve as in Fig. 117, Q will be large and if the line became

Fig. 118.—Elastic/plastic curves showing the roll-gap transfer function for a thick soft material



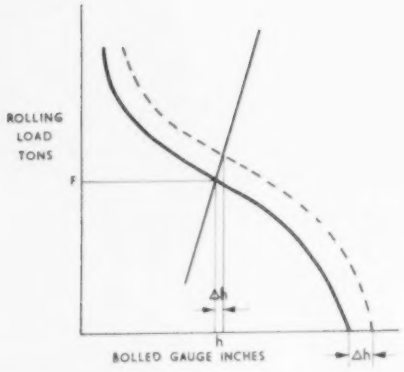


Fig. 119.—Elastic plastic curves showing the effect of a change in ingoing gauge with a stiff mill

vertical, would be infinity. In the case of the soft material, shown in Fig. 118, the value of Q is small and if it was zero, the plastic curve would be horizontal at that point. In practice, it is possible for Q to be infinity under limiting thickness conditions, but it is never possible to reach the case when Q is zero.

The Effect of Mill Stiffness on Gauge

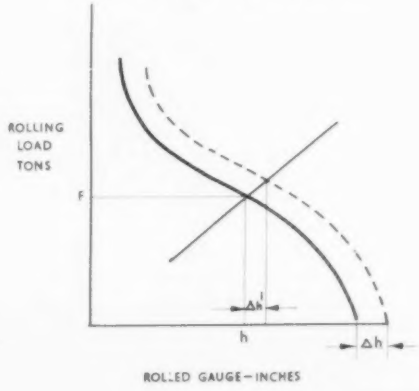
If an infinitely stiff mill was possible in practice, there would be no spring whatever and the rolled gauge would be exactly the same as the initial roll-gap setting. The nearest practical approach to this is a stiff design, such as the pre-stressed SKF mill in which the housing spring can be made very small. Experiments have been carried out with tungsten-carbide rolls which have a very high modulus of elasticity and, therefore, a greater resistance to flattening under load. By using these rolls in conjunction with heavy backing rolls and a pre-stressed housing, the nett result is a very stiff mill in which the rolled gauge is only slightly greater than the roll-gap setting. In a stiff mill a great deal of energy is stored in the mill and variations in ingoing gauge are "ironed out" to a great extent. This can be seen by consideration of the mill modulus. A sudden increase in ingoing thickness tends to force the rolls further apart, but if the mill modulus is high, as in a stiff mill, a much greater force is required to move the rolls a given distance apart than in a soft mill and the variation in the ingoing gauge is reduced considerably as the material passes through the rolls. In a stiff mill the screw movement required for a given correction will be relatively small, but will require a great deal of torque on the screw.

In the case of a soft mill, the rolled gauge is considerably greater than the initial roll-gap setting. This in itself is not a serious disadvantage in a mill, provided that the rollerman knows the amount of spring he will have for different rolling schedules and sets the mill accordingly. There is, however, the disadvantage that in a soft mill any variations in ingoing gauge will persist through the mill and will not be "ironed out" as in a stiff mill. Again, this will be seen by consideration of the mill modulus which will be small and a relatively small change in ingoing thickness will be sufficient to force the rolls apart and give an error in the finished gauge. In a soft mill the screw movement required for a given correction will be relatively large, but the torque required will be small. The overall power required at the screw will be almost identical whether the mill is stiff or soft.

The elastic plastic curves can be used to illustrate the effect of mill stiffness.

Fig. 119 shows the hypothetical case of a stiff mill with an equilibrium position at rolling load F and rolled gauge h. The modulus is high, giving a steep slope to the elastic line. If now there is a change in ingoing thickness, the plastic curve will move parallel to itself a distance $\triangle h$ equal to the change in ingoing thickness, as shown dotted in Fig. 119. Assuming no change in screw setting, the change in rolled gauge will then be $\triangle h'$, as shown in the diagram, and it will be seen that $\triangle h'$ will be less than $\triangle h$. The stiffer the mill the more nearly does this elastic line approach the vertical and, of course, if it was possible to have an infinitely stiff mill giving a vertical line, $\triangle h'$ would be zero for any value of $\triangle h$ and any ingoing variation would be "ironed out" completely. In the case of a soft mill the elastic line has a much smaller slope and it will be seen from Fig. 120 that a change of $\triangle h$ in ingoing thickness gives a change of $\triangle h'$ in rolled thickness, where $\triangle h'$ may approach, or in extreme conditions very rarely found in practice, may be greater than $\triangle h$.

Fig. 120.—Elastic plastic curves showing the effect of a change in ingoing gauge with a soft mill



The Effect of Stiffness on the Automatic Control of Gauge

Mill spring has been used ingeniously by the British Iron and Steel Research Association in a high-speed form of automatic control of gauge. It has been shown that the gauge coming out of a mill at any instant is the sum of the roll-gap setting and the mill spring at that instant. When investigating the possibility of automatic gauge control, the British Iron and Steel Research Association scientists evolved this equation and decided to try and measure the roll setting and the mill spring electrically, so that they could be added together electronically at high speed to give a measurement of gauge.

The measurement of the roll setting at any instant is relatively simple in a normal screw type mill, as the roll-adjusting screws themselves can be used as micrometers. Provided the measurement is made at a point where there is no backlash, the screws give a very high degree of accuracy and in several mills which have been checked by accurate instruments, the positional errors are only fractions of a thousandth of an inch. In order to avoid backlash in the initial experiments, an electrical resistance wire was mounted on a drum which was bolted directly to the top of each screw. A pick-up touched this resistance wire and shorted out a portion of it, depending on the screw position, and an accurate measurement of the resistance of the remaining portion of the wire gave an electric signal directly proportional to the screw position. This method can give a high degree of accuracy, but is not robust enough for a production mill and it is now usual to use a Selsyn on the end of the screw, which measures the number of degrees the screw moves through from zero position.

It is a very difficult matter to measure mill spring directly and transform it to an electric signal, but it is relatively easy to measure the rolling load and obtain an electric signal proportional to this load. If the mill modulus curve is a unique reversible and repeatable straight line for any given mill and the slope of this line is M, the mill spring at any instant will be $\frac{M}{F}$ where F is the roll force at that instant. As M is a constant for a given mill it is obvious that the mill spring is directly proportional to the rolling load and if an electrical signal is obtained which is proportional to the rolling load, this can be converted directly to mill spring.

Methods of measuring roll load will be discussed later, but by using electronic load meters a high accuracy can be obtained with a fast response.

The British Iron and Steel Research Association automatic gauge control system, therefore, consists of some means of measuring rolling load electronically, together with some means of measuring the screw position electrically and adding these together to give the final rolled gauge.

Having obtained a rapid and accurate measurement of gauge at any instant, there are several ways in which this can be used to control the gauge to a pre-determined figure. In a normal screw-operated mill it is possible to have a Ward-Leonard drive to the screws with a signal feeding back constantly from the gauge measuring system. In this case the gauge required is set on a dial, giving an electrical signal proportional to this gauge and this is compared with the gauge measurement, any difference between the two being correct by feeding the error in to the Ward Leonard system of the screwdown. The disadvantage of this is that the screws are moving continually and thread wear becomes a problem. As there is always a rolling tolerance on gauge, it is more usual to have a gate set to a predetermined tolerance on each side of the nominal gauge and the screw motors are only energized when the measured gauge falls outside this tolerance.

In theory, this automatic gauge control system will work equally well whether the mill is soft or hard. The electronic system is fast enough to measure the gauge and initiate a rapid correction, but in a normal screw type mill, there is a considerable lag in transferring the correction signal through the contactor gear to powerful screwdown motors. If, therefore, the mill is very soft, with little inherent "ironing out" of gauge, the automatic gauge control will be lagging behind the gauge changes. If, however, the mill is very stiff there will be a considerable "ironing out" of gauge errors and the gauge control correction will be required less often. A stiff mill is, therefore, preferable to reduce the work done by the gauge control.

In order to make use of the speed of response of the BISRA system of automatic gauge control, it would be preferable to use a hydraulic method of loading the rolls. There are many mills operating with simple hydraulic jacks, but so far the development of a hydraulic system of gauge control has not reached a production basis. Initial tests, however, have shown that it is preferable to keep the mill as stiff as possible and the aim has been to keep the volume of fluid in the system as small as possible and to lock the system completely when rolling under constant load. In theory, it is possible to make a hydraulic loading system so rapid that a soft mill can be used, but again this throws extra work on the control system.

Mill Spring and Taper Rolling

In all normal work, the rollerman's aim is to maintain a constant gauge, both across the width and along the length of a bar or sheet. There are,

however, occasions when a taper may be required, particularly in the aircraft industry. The present trend is to design wings with light-alloy sheet covering which tapers in thickness from the root of the wing to the tip. Similarly, light-alloy main wing spars are required, which taper from the root to the tip. It is common practice when making a wing spar, to take a rolled section and mill it to obtain the taper along the length. This takes a great deal of time and the wastage is very high, as something in the order of half the total weight is removed in the milling process. Similarly, thin, light-alloy sheets have been milled to a taper gauge, but this is even more costly than machining a spar. Various experiments have been carried out with the object of rolling the sheet or spar to the correct taper, but so far little progress has been made on a production basis. When rolling a taper it is not a simple matter of screwing down as the material passes through the rolls to give the variation required from end to end, as this involves extremely high rolling loads at the thin end of the wedge and there is difficulty in obtaining an accurate taper. In addition to this, the mechanical properties of the material would vary considerably along the length from relatively soft at the thick end to very hard at the thin end.

There are several possible methods of obtaining an accurate taper in several passes and most of these would apply to hot rolling of taper billets from parallel stock, or cold rolling of strip from constant gauge material. These methods can be broken down into two major divisions.

1. The material can be rolled down normally to give parallel stock of the correct thickness for the thick end of the wedge, all tapering being carried out in the final passes.

2. The taper can be formed roughly early in the breaking-down process, all subsequent reduction being carried out on the tapered material.

Method 1 appears on the face of it to be the most attractive commercially, as the major part of the reduction is on a normal mill at high speed. By this method, however, there will be a substantial variation in the mechanical properties along the length of the finished bar or sheet and it will be necessary to anneal and taper skin pass to obtain a reasonably uniform product.

Method 2 seems to be rather more complicated, but in this case the major part of the reduction is on stock of approximately the correct taper and the draft throughout each pass is more or less constant after the taper has been formed roughly in the early stages of breaking down.

The choice between two possible methods will depend on the mechanical properties required and the type of mill and control used.

Whatever the method used to give the final taper, at some stage in the rolling it will be necessary to change from parallel stock to stock with a taper and the actual forming of the taper can be carried out in one of several ways.

This has been discussed at some length by the author in a published article and only sufficient is included here to show the effect of mill spring on a tapered gauge.

It would appear to be a simple problem to calculate the rate of screwdown required in relation to mill speed to obtain any given taper, and allowing for various factors such as forward slip and motor droop, this is possible. It is essential, however, to compensate for the mill spring by :—

(*a*) Change in the roll-gap transfer function.

(*b*) Allowance for non-linearity of the mill-spring curve.

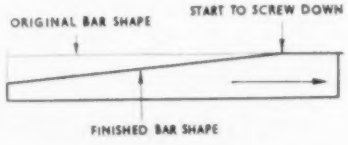
It has already been shown that the actual reduction obtained on a bar is only a fraction of the screw movement. If the distance moved by the screws is S inches, then the actual reduction in gauge of the bar will be $S \times f$ where f is the roll-gap transfer function.

If a parallel bar is being rolled, and at a certain point the screws are brought down at a calculated rate to give a taper, as in Fig. 121, it is obvious that the rolling load will be increasing steadily. As the draft is increasing also, the bar being rolled will become progressively harder and the roll-gap transfer function will be constantly changing. In order to maintain a constant rate of taper, therefore, the rate of screwdown will have to be increasing continually in relation to the speed of the bar through the rolls. In practice it is possible to compensate for this by trial-and-error methods. If a number of bars are rolled at different speeds, all with a constant rate of screwdown, it should be possible to arrive at a combination of speeds giving the correct gauge at the start and finish of the taper. In theory, the rate of change of the taper will not be truly constant, as the rate of work hardening is not directly proportional to the reduction over the whole range. Any errors will be well within normal commercial tolerances.

In discussing the formation of a taper and the effect of the roll-gap transfer function, it has been assumed that the mill spring is directly proportional to the load. The shape of the mill-spring load curve has already been discussed at some length and shown to have a considerable curvature at the

(*Continued in page* 146)

Fig. 121.—*Rolling a tapered bar*



SHEET METAL DATA SHEET 14

Manufacture of Tin Boxes—2

Compiled by J. W. Langton, M.B.E., B.Sc.(Lond.), M.I.Mech.E.

NON-CIRCULAR SEAMLESS BOXES

THIS data sheet deals with the second division of non-circular shapes, with solid drawn (*i.e.* seamless) lids and bodies. The majority of the shapes are rectangular, but other regular geometrical shapes follow the same production pattern.

TYPES

In most types, the lid fits over the body. If the lid is a loose separate piece, it is a slip-lid type; if hinged to the body, a hinged-lid type.

The shape of the top of the lid can vary but a flat or domed lid is usual. Unless the shape is special, as say on the vacuum-lidded tobacco box, it should not affect the drawing operation. The same remarks apply to the base of the body.

The overlap of lid on body is entirely arbitrary, but the lid depths are usually made the minimum for the purpose, $\frac{1}{2}$ in. to $\frac{5}{16}$ in. being common.

Removal of the raw edges on lid and body can be secured by curling the lid externally or hemming it (*i.e.* turning in and flattening) internally on the body by curling inside, or hemming inside. The hemming is by far the less common, being more difficult.

Here again as in the first data sheet on this container manufacture, we are dealing with the common standard types *i.e.* tobacco and tablet boxes and the like. The flat 50-cigarette container with locked corners is here regarded as a special type, being not in real terms seamless.

SIZES AND SUBSTANCES

Most sizes are determined so that they can be produced in about 30-ton C-frame presses. Depths again seldom exceed $1\frac{1}{4}$ inches. The size of the body corner radii is always important. The smaller the radius, the more difficult the drawing, and the corner radius size directly affects the depth which can be drawn. A very good general rule is that depths can be drawn up to about four times the corner radius. The body size and corner radius is practically always set to be produced in one draw.

The tinplate substances used vary from 0.008 to 0.0125 in., the lightest substance that will serve being chosen. The more difficult the body draw, usually the heavier the substance called for; deep-drawing-quality material is a possible necessity in the very awkward draw cases. Lids generally require only light substances.

BODY AND LID SIZES

The relative sizes of lid and body have to be established correctly in the first cut and draw dies, as any subsequent operations usually affect these sizes little. The relative determination is done largely by trial and error. The body itself tapers outwards from the base, due to spring, and the amount varies with the particular circumstances, such as box dimensions, tinplate quality, etc.

Hinged-lid types require a greater allowance across the box width because obviously the lid is at an angle when first being pressed over the body. This extra allowance over normal can vary from 0.020 to 0.035 in. The fitting at the corners also is very important.

BASIC MANUFACTURING OPERATIONS

Slip lid, body trimmed, lid untrimmed.

(1) Cut Sheets to Size.
(2) Cut and Draw Lid.
(3) Cut and Draw Body.
(4) Trim Body.

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Manufacture of Tin Boxes—2 (Cont.)

If **lid curling is added,** there is an additional operation of

(5) Curl Lid.

If **internal body curling** is added a further addition

(6) Curl Body.

For a Hinged-lid Type the additional operations for hinging are

(7) Hinge Pop Body.
(8) Bend Hinge Lug of Lid.
(9) Straighten, Cut Off and Insert Hinge Wire.
(10) Close Lid Hinge Lug Over Wire.

If the lid is hemmed inside the extra operations are

(11) Turn Over Lid Edge.
(12) Close Edge or Hem Inside.

If the body is hemmed inside the extra operations are

(13) Notch Body at Four Corners.
(14) Turn Edge Inside.
(15) Close Edge Inside.

PLANT USED

Starting with the slip-lid type, and the body trimmed bu not curled, the operations and basic plant would be:

(1) Cut Sheets—Guillotine or Gang Slitter
(2) Cut and Draw Lid—Power Press
(3) Cut and Draw Body—Power Press
(4) Trim Body—Special Irregular Trimming M/C

Irrespective of the demand, the plant used varies little, but production figures fairly widely with the particular set up.

An average figure for a box about 4 in. × 3 in. × $\frac{3}{4}$ in. deep body would be about 20,000 per day.

If lid curling is added, then an additional press is required. An alternative is to use an irregular-type seaming machine, but this can be slower.

If body curling is added, another press is called for.

For the addition of hinging the following additional plant is required:

Hinge Pop Body—Bench Power Press or Dual Operation Press

Bend Hinge Lug of Lid—Bench Power Press or Dual-Operation Press

Straighten, Cut-Off and Insert Wire—Special Hinge Wiring Machine.

Close Hinge Lug over Wire—Foot Press or Bench Power Press.

At the same time as the hinge pops are produced it is often necessary to produce a bead or pop at the opposite side to assist opening. A similar bead is often added to the front of the lid when bending the lug. The special dual-operation press is designed to do this double work on either component expeditiously.

The use of the special hinge wiring machine is highly desirable. An alternative method is to buy in the wires, straightened and cut to length, and insert by hand. This is much slower.

In computing the number of operations required, regard should be paid to operations not mentioned ancillary to the production operations *i.e.*, those of wiping and packing and wrapping. Most of these tin boxes must be free from any grease, which may be necessary to add during drawing and therefore they must be wiped before despatch. Both wiping and packing could require a number of operations.

It is usual to connect various machines by simple carrier conveyors.

With regard to the plant for the hemming operations 11 to 15, all except the notching are carried out in press tools. The notching can be carried out in a special press tool, or better still by a special-purpose four-slide notching machine.

SHEET METAL DATA SHEET 14

Manufacture of Tin Boxes—2 (Cont.)

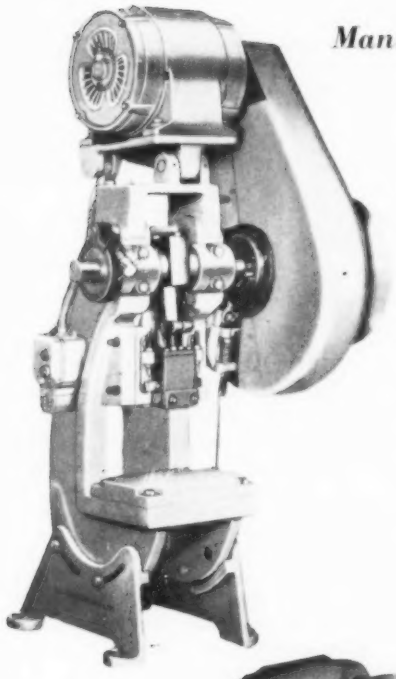


Fig. 1 (top left).—Bench power press

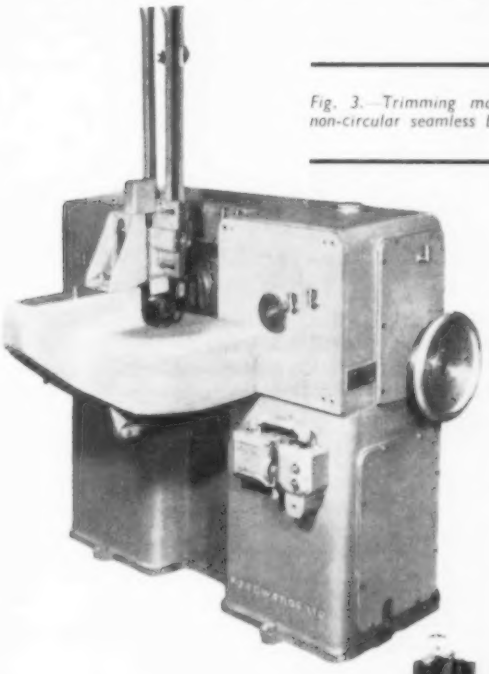


Fig. 3.—Trimming machine non-circular seamless bodies

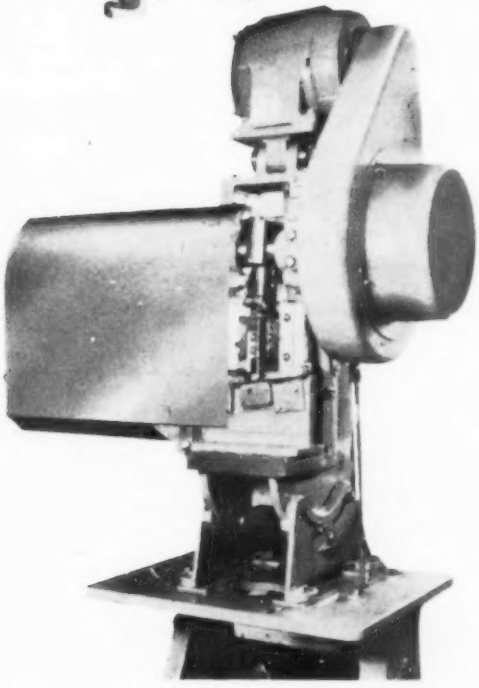


Fig. 2 (bottom left).—Hinge wiring machine

Fig. 4 (right).—Dual operation press

Theory and Practice of Flat Rolling

(*Continued from page* 142)

toe. If the load is maintained at a sufficiently high level to avoid the toe of the curve, the assumption that mill spring is directly proportional to load will be correct for all practical purposes and the above argument will hold. If, however, the load falls to a small value, the mill spring becomes progressively greater in relation to the load and the roll-gap transfer function falls at an increasing rate as the load approaches zero.

In the case of a taper being formed from a parallel bar, the load will be very small at the start of the taper and will increase as the taper is formed. Initially, therefore, the mill spring will be greater than expected, due to the toe of the modulus curve and the slope of the resulting taper will be less than that required. As the load increases to the linear part of the modulus curve, the taper will increase until the correct slope is obtained as in Fig. 122.

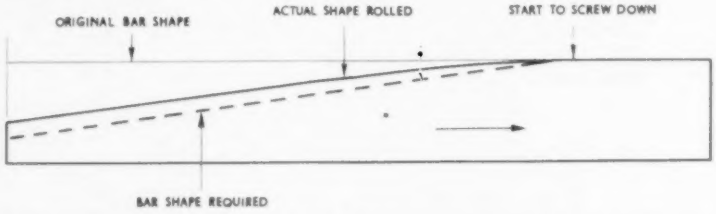


Fig. 122.—Effect of mill spring on the rolling of a tapered bar

This can be overcome in practice by rolling the parallel bar with a draft sufficiently high to ensure that the load is above that required to reach the linear part of the modulus curve before the taper is started.

(*Series to be continued*)

We would remind readers that this series of articles on "The Theory and Practice of Flat Rolling" by the late C. W. Starling, will be published as a book later this year by The University of London Press Ltd. of Little Paul's House, Warwick Square, London, E.C.4. The demand for extra copies of these articles has been very high and we regret that no copies are available of those instalments published in 1960.

Welding of Aluminized Steel Sheet

(*Continued from page* 98)

tion, labour costs, etc., the overall effect is an increase of only a few per cent. Further, there are compensations in that welding can be carried out more rapidly with stainless-steel filler rods; using ten cubic feet of argon per minute, a current of 120 ampères, and 0.035 inches diameter wire, welding speeds of over 2 feet per minute can be readily exceeded.

Argon-arc butt welding can, of course, be carried out either manually or by machine: in the latter case about a foot of wire per foot run of weld would be used. The appropriate thickness of wire is selected on the basis of sheet thickness, and typical values are given below in Table IV.

TABLE IV

Sheet thickness	Filler-rod diameter
20 gauge	$\frac{1}{16}$ in.
18 gauge	$\frac{1}{16}$ to $\frac{3}{32}$ in.
16 gauge	$\frac{3}{32}$ in.

Spot welding can be carried out by the argon-arc process, and Fig. 6 shows this technique being used in vehicle body construction.

A major advantage associated with the welding of aluminized steel is that the user is assured of a complete absence of welding defects that could arise from the composition of the steel. It is well known that a high sulphur or phosphorus content can lead to weld porosity, but "ALUDIP" is manufactured from steel purchased and tested to the most rigid requirements and defects having their origin in such causes are quite unknown.

Acknowledgements

The authors wish to express their appreciation of the assistance given in the writing of this article by British Oxygen Company Ltd. and Sciaky Electric Welding Machines Ltd., who kindly provided data and photographs.

References

1. British Oxygen Co. Ltd., North Circular Road, N.W.2.
2. Sciaky Electric Welding Machines Ltd., Falmouth Road, Slough, Bucks.
3. "ALUDIP" is the registered Trade Name of aluminized steel sheet manufactured by Coated Metals Ltd., Palmerston House, E.C.2.

INSTITUTE OF SHEET METAL ENGINEERING

Forthcoming Activities and New Members

INVITATIONS FOR PAPERS FOR 1961 CONFERENCE

THE programme for the Annual Conference of the Institute to be held in the late Autumn of 1961 will include a session devoted to the discussion of papers on the specialized theme of "Problems Relating to Materials, Feeding and Tooling in High-Speed Presswork Production", in addition to others on more general aspects of sheet-metal working and utilization. Offers are invited of papers relating either to the special theme or to any other subject within the purview of the Institute, and all such offers will be considered by the Technical and Papers' Committee for inclusion in the programme.

Anyone desirous of submitting a paper to this Conference should, as soon as possible, write, stating the proposed title of the paper and detailing briefly the manner in which the subject would be dealt with, to the Hon. Secretary, I.S.M.E., John Adam House, 17/19 John Adam Street, Adelphi, London, W.C.2.

LIVERPOOL MEETING

ON January 11 the North-West Branch of the Institute departed from their customary practice of holding meetings in Manchester and broke new ground by arranging an additional meeting in Liverpool. The meeting took the form of a showing of a number of films of technical and general interest and attracted an attendance of a little short of 100. The Branch chairman, Mr. T. M. Lessar (Manchester Metal Works Ltd.) took the opportunity of briefly addressing the meeting and outlined to them the principal aims and activities of the Institute. He expressed the hope that the meeting would be the forerunner of many others and that, if the obvious evidence of interest was maintained, it would be possible for the branch to establish a section in the area.

NEW MEMBERS

At the last meeting of the Council of the Institute the following were elected to membership in the grades shown :—

Company Members

Barber and Colman Ltd., Sale, Cheshire
Normec (M/C) Ltd., Rochdale, Lancs.
The Edmonton Steel Strip Co. Ltd., Edmonton, London, N.18.

Members

L. B. Robinson (Bristol Tool and Gauge Co. Ltd.)
J. C. Alderson (A1-Metal Craft (Coventry) Ltd.)
R. Wood (Harris College of Further Education, Preston)
Wm. Morgan (Jaguar Cars Ltd.)
E. Bannister (Matthew Boulton Technical College, Birmingham)
R. F. Whitehouse (Standard Triumph International)
Thos. Bebbington (Barber and Colman Ltd.)
H. W. Heap (Bolton Technical College)
A. F. Lewis (Crauford Stainless Steel Co. Ltd.)
R. J. Wakelin (A.W.R.E., Aldermaston)
A. Fisher (Tubes Ltd.)
T. S. Fearnley (De Havilland Aircraft Co. Ltd.)
L. Buckley (Bolton Technical College)
Robt. Smith (Bolton Technical College)
John Broadbent (Broadbent Hardward Ltd.)
J. E. Evans (Airstream Metal Products Ltd.)
L. H. Williams (John Hallock Ltd.)

Associates (Class I)

G. Cleworth (Bolton Technical College)
P. Dobby (Birkenhead Technical College)
L. D. Briers (Rolls Royce Ltd.)
D. W. Adcock (Rolls Royce Ltd.)
L. Orrock (Bognor Regis Technical Institute)
W. G. Lamb, F.M.T. Eng. and Design Co. Ltd.)

Associates (Class II)

F. H. G. Cooke, M. H. Attwood, B. W. Newman, D. W. Eggbeer, R. D. Britton (Parnall and Sons Ltd.)

Students

S. Holme (De Havilland Aircraft Co. Ltd.)
C. M. Parry (De Havilland Aircraft Co. Ltd.)
T. G. Tanswell (United Kingdom Atomic Research Establishment).

Résumés des Principaux Articles

mémoire, de l'Ordnance Factory (Usine d'Armements National) de Birtley, présenté à la récente Conférence de l'Institute of Sheet Metal Engineering (Institut des Ingénieurs Tôliers) au sujet du refoulage à froid de l'acier, renseigne sur la conception et la fabrication des matrices à refouler, les pièces en acier rapportées, les matrices au carbure de tungstène, la lubrification de l'outillage, l'étude de poinçons à employer (résultats démontrés par études photo-élastiques), les aciers d'outillage et le traitement thermique, la déviation des pièces par rapport aux dimensions des outils, le prix de l'outillage et la durée probable de son service. Illustré de nombreux dessins et photographies, ce mémoire, fort bien détaillé, est complété par un compte rendu du débat qui a suivi sa présentation à la Conférence.

Aciers Forges à Froid page 123

Par F. Griffiths

Ce mémoire a également été présenté à la Conférence de l'Institute of Sheet Metal Engineering (Institut des Ingénieurs Tôliers) sur le refoulage à froid de l'acier. Il est publié en même temps que le rapport sur le débat qui en a suivi la présentation. L'auteur, qui est l'ingénieur en chef du développement de la production de la British Motor Corporation, présente les conclusions auxquelles il est arrivé au sujet du procédé, du point de vue de la production de pièces pour sa propre industrie. Il exprime une opinion intéressante et particulière au sujet de la conception des presses que demande son industrie et il renseigne le lecteur sur les variations considérables dans les prix proposés par cinq constructeurs différents pour la création d'une presse spéciale. Le mémoire comprend des illustrations de pièces caractéristiques et leurs phases de production.

Introduction à la Théorie et la Pratique du Laminage de Tôles Planes—6 .. .. page 135

Par C. W. Starling, B.Eng., A.M.I. Mech.E.

L'effet de l'élasticité du laminoir sur le calibrage est le thème principal de ce chapitre du livre du regretté C. W. Starling (qui sera publié par l'University of London Press Ltd. après avoir paru en feuilleton dans SHEET METAL INDUSTRIES). *Le sujet principal est examiné sous les rubriques suivantes: module du laminoir, module du cylindre et de la cage, courbe élastique plastique, effet de l'écart entre cylindres, effet de la rigidité du laminoir sur le calibre et le contrôle automatique du calibre, flexion du laminoir et laminage conique.*

Zusammenfassungen der Hauptartikel

Birtley, zur Vortragreihe über Kalt-Strangpressen von Stahl auf der Konferenz des Institute of Sheet Metal Engineering behandelt die Konstruktion von Presswerkzeugen, Stahleinsätze, Wolframkarbidwerkzeuge, Schmierung von Werkzeugen, Stempelkonstruktion (mit photoelastischen Studien), Werkzeugstähle und Wärmebehandlung, Abweichung der Fertigteile von den Werkzeugabmessungen sowie Werkzeugkosten und -lebensdauer. Dem aufschlußreichen Vortrag sind viele Zeichnungen und Lichtbilder sowie die anschliessende Diskussion beigefügt.

Kaltschmieden von Stählen Seite 123

Von F. Griffiths

Dieser Vortrag gehört ebenfalls zu den auf der Konferenz des Institute of Sheet Metal Engineering über das Kalt-Strangpressen von Stahl gehaltenen und ist zusammen mit der sich an ihn anschliessenden Diskussion veröffentlicht. Der Verfasser, Chefingenieur für die Fertigungsplanung bei der British Motor Corporation, gibt seine Ansichten über das Verfahren, zu denen er auf Grund seiner Erfahrungen bei der Herstellung von Teilen für seine spezielle Industrie gekommen ist. Er macht einige interessante und polemische Bemerkungen über die Konstruktion gewisser von ihm benötigter Pressen und zitiert die grossen Preisunterschiede in den Angeboten von fünf verschiedenen Pressenherstellern für eine Specialpresse. Typische Fertigteile und ihre verschiedenen Herstellungsstadien werden in Abbildungen gezeigt.

Einführung in die Theorie und Praxis des Blechwaizens—6 Seite 135

Von C. W. Starling, B.Eng., A.M.I. Mech.E.

Der Einfluss der Walzenfederung auf die Dicke ist das Hauptthema dieses Kapitels im Buch des verstorbenen Verfassers (das nach Veröffentlichung in Fortsetzungen in der Zeitschrift SHEET METAL INDUSTRIES *von der University of London Press Ltd. herausgegeben wird). Das Hauptthema wird unter den folgenden Überschriften behandelt: Walzwerksmodul, Walzen- und Ständermodul, die elastisch-plastische Linie, die Walzspalt-Übergangsfunktion, der Einfluss der Walzwerkssteifigkeit auf Blechdicke und automatische Dickenregelung, Walzwerkfederung und verjüngtes Walzen.*

Resúmenes de los Artículos Principales

de Birtley en la reciente Conferencia del Instituto de Ingeniería de la Chapa Metálica y que se refiere a la extrusión en frío del acero ofrece información sobre la concepción de troqueles para extrusión, insertos de acero, troqueles de carburo de tungsteno, lubricación de herramientas, creación de punzones (mostrando resultados por medio de estudios fotoelásticos), aceros para herramientas y tratamientos térmicos, deviación de componentes de las dimensiones de las herramientas y coste de herramientas y predicción de su duración. Ilustrado con múltiples dibujos y fotografías este trabajo informativo va seguido de la discusión que tuvo lugar después de su presentación en la Conferencia.

Aceros Forjados en Frio pagina 123

Por F. Griffiths

También este trabajo fué presentado durante la Conferencia sobre la extrusión en frío del acero del Instituto de Ingeniería de la Chapa Metálica y se publica juntamente con la discusión a que dió lugar su presentación. El autor, ques es el Ingeniero Jefe encargado del fomento de la producción de la British Motor Corporation, describe las conclusiones a que ha llegado sobre este procedimiento desde el punto de vista de la producción de elementos para su propia industria. Hace algunas observaciones interesantes y sujetas a discusión sobre la concepción de prensas que necesita y nos informa sobre la gran variación de precios cotizados por cinco fabricantes diferentes por una prensa especialmente creada. Ilustran este trabajo algunos elementos típicos y sus fases de producción.

Presentando la Teoria y la Practica del Laminado Plano —6 pagina 135

Por C. W. Starling, B.Eng. A.M.I.Mech.E.

El efecto que sobre el calibre tiene la deformación del tren laminador constituye el tema principal de este capítulo del libro del difunto autor (que publicará la University of London Press Ltd. después de su publicación por episodios en SHEET METAL INDUSTRIES). *Se pasa revista a este tema bajo los encabezamientos de módulo del laminador, módulo de los cilindros y alojamiento, curva elástica plástica, función de transferencia sobre el espacio entre cilindros, el efecto de la rigidez del laminador sobre el calibre y la deformación del laminado y el laminado ahusado.*

SHEET METAL NEWS

FEATURING EVENTS AND PERSONALITIES IN THE INDUSTRY

PROSPECTS FOR STEEL

HAVING achieved a record year in steel production and export, trends in the steel industry promise a continuing high level of prosperity. A total of £900 million has already been spent on development since the war and the industry has decided to spend a further £450 million by 1965 to boost the capacity, which increased to 27 million tons in 1961, to over 34 million tons; it is estimated that this level of capacity is more than sufficient to meet requirements, according to a report from the British Iron and Steel Federation.

Most sections of the steel industry were fully stretched throughout 1960 and crude steel production averaged some 93½ per cent of effective capacity. While the requirements of the railways and wagon builders, coal mines and shipyards, and of the oil industry, which suffered severely during the recession, continued at a low level, the high and increasing demand for cars, household durables and food containers which had kept the strip mills busy during the recession continued throughout the year and the expanding flow of orders from the engineering and constructional industries was met by high outputs of most heavy and light steel products. Steel consumption in the United Kingdom for 1960 as a whole was about 2½ million tons (14 per cent) higher than 1959; the proportion of indirect steel exports to this increase was relatively small, about 150,000 ingot tons, and although exports of motor-cars showed a further substantial rise, exports of rolling stock and of ships were again lower than the previous year. Direct exports of steel, which had already shown signs of improvement in 1959, rose by a further ½ million ingot tons in 1960 to reach a post-war record level of 4.2 million tons in spite of the fact that in some cases, particularly sheet, tinplate, wire rods and small bars, exports were restricted to satisfy the high level of home demand. Imports of steel, mainly sheet, much of which was put into stock, amounted to 1½ million ingot tons in 1960 (about 6 per cent of total demand) compared with just under ½ million ingot tons in 1959. As a result of these changes, crude steel production last year amounted to some 24 million tons, 20 per cent more than in 1959. Steel consumers and merchants who had reduced their stocks continuously from March to December, 1959, began to rebuild them during the year and the total stockbuild was probably in the region of more than 1 million tons; steel sheet accounted for almost half the total stockbuild during the first nine months of 1960, partly because the high rate of import turned out to be in excess of consumption requirements.

The industry's total expenditure on expansion and replacement in 1960 was about £130 million, approximately 25 per cent more than the previous year; the most outstanding developments completed during the year were the four-high plate mills at Consett and a new

(*Continued in page* 150)

F. J. EDWARDS LTD. of 359-361 Euston Road, London, N.W.1.held their annual staff dinner on December 22 at the Empire Rooms, Tottenham Court Road; a full dinner was provided for 280 members of the London staff and their wives, all of whom were welcomed by Mr. H. A. Johnson, the managing director, and Mrs. Johnson. The dinner was followed by a cabaret show provided by the Champagne Cabaret. The photograph below shows the directors and their wives.

Prospects for Steel

(*Continued from page* 149)

melting shop and slabbing mill at South Durham's new South Works. Other developments included expansion of coke, sinter, pig iron and rolling capacity at John Lysaght's Scunthorpe Works and the reconstruction of the Hallside Works of Colville's for the production of special and alloy steels, including a new billet mill. These developments not only helped to expand capacity but also led to increased efficiency; output per man year rose above the previous peak level of 1957 and the coke rate in blast furnaces was further reduced to under 16½ cwt. due mainly to the further increase of ½ cwt. per ton in the use of sinter.

Production demands for 1961 are not expected to exceed the output for 1960 to any great extent and on present evidence it is expected that demand will support an output of about 24½ million tons—about 90 per cent of the estimated effective capacity. The rise in home consumption of steel will probably be smaller than the increase for last year since there have already been indications of changes in the pattern of home demand with orders for motor cars and household durables falling off, and the requirements of the capital goods continuing to grow; it is expected that the increase in home consumption will be in the region of 2 to 3 per cent or about ½ million ingot tons above the 1960 peak. Although the world demand for steel is not encouraging, it is anticipated that the exports will exceed the post-war record achieved in 1960.

The general trend of development is towards the strip mill section of the industry. The first stage of the new Spencer Works being erected by Richard Thomas and Baldwins at Llanwern, Newport, including the 68-in. continuous hot strip mill, the L.D. steelmaking plant and the 66-in. cold reduction mill is due for completion in 1962, Colville's new cold reduction mill at Gartcosh is due to come into operation in the latter part of 1961, while the 60-in. hot strip mill at Ravenscraig is due to start rolling in the middle of 1962. During 1961, the Steel Company of Wales will extend its steelmaking capacity at its Abbey Works and instal the new 2-strand continuous casting plant for slabs, while John Summers are making substantial additions to their sinter and rolling capacity.

Apart from the strip mill developments, the outstanding developments due for early completion are the additions of universal beam mill stands to the heavy section mills at Colville's Lanarkshire Works, South Durham's Cargo Fleet Works and the United Steel Companies' Appleby-Frodingham Works. Billet capacity will be expanded by the completion of the two new rotor furnaces for pre-refining and the commissioning of the new continuous billet mill at Richard Thomas and Baldwin's Redbourn Works. Other important developments include the new melting shop at Consett with two L.D. and two Kaldo vessels and the completion of South Durham's new South Works by the addition of a blast furnace and further steelmaking capacity. The result of these developments, which exceed anything planned on the Continent, will result in the capacity for 1962 being extended to over 30 million tons and further developments subsequently, including major schemes at Park Gate, Dorman Long, English Steel, Steel, Peach and Tozer and Appleby-Frodingham will result in the 1965 capacity exceeding the present capacity of Western Germany.

COURSES IN WELDING

A SERIES of courses arranged by the Institute of Welding of 54, Princes Gate, Exhibition Road, London, S.W.1, at the School of Welding Technology for the period November, 1960, to March, 1961, include the following courses still to be recommended:—

Course D.5/3, "Non-Destructive Weld Examination," February 13-17, 1961, fee £24 for non-members, £18 for members.

Course D.22, "Welding of Atomic Energy Plant," February 27 to March 3, 1961, fee £18 18s. for non-members, £14 3s. 6d. for members.

Course D.17/1, "Advanced Course for Welding Engineers," March 13-17, 1961, fee for non-members £24, members £18.

Course D.4/2, "Resistance Welding—Technology and Design," March 27-30, fee for non-members £20, members £15.

Other courses provisionally arranged until December, 1961, are D.37, "Advanced Ultrasonic Inspection," D.8/3, "Welded Structures," D.33, "CO_2 Arc Welding" during May, D.1/4, "Welded Pressure Vessels", and D.34, "Welded Metallurgy" during October D.13/3, "Residual Stresses and Stress Relief," D.12/3, "Practical Control of Distortion," and D.28/1, "Welding for Junior Management" during November.

OLD ESTABLISHED COMPANIES MERGE

FOLLOWING the retirement of Mr. T. K. Hawkins, chairman and managing director of James Farquharson and Sons Ltd., Park Parade, Harlesden, London, N.W.10, G. F. E. Bartlett and Son Ltd., of Maylands Avenue, Hemel Hempstead have acquired a controlling interest in the company. While the two companies will continue to operate in their distinctive spheres, under the chairmanship of Mr. E. G. A. Bartlett, the general policy will be co-ordinated to provide a complete service to all catering establishments, schools, factory canteens, hospitals and other organisations.

The new board of James Farquharson and Sons Ltd., will be—Mr. C. R. M. Thomas, who has been appointed managing director, and two other directors appointed from G. F. E. Bartlett and Son Ltd.,—Mr. G. R. Westley and Mr. D. E. Marshall. Mr. Westley is the sales director of G. F. E. Bartlett and Son Ltd., and Mr. Marshall their buyer and a director of Bartlett Motors Ltd. This development forms part of a steady expansion programme by Bartlett's who, since their move to Hemel Hempstead in 1954 have already completed a 20,000 sq. ft. extension to their factory at Maylands Avenue and have improved their manufacturing processes to enable better equipment to be produced at reasonable cost.

LECTURE COURSES AT BIRMINGHAM "TECH"

A COURSE of eight lectures on "Modern Developments in the Theory and Practice of Steel Heat Treatment" to be held on successive Tuesday evenings, commenced on January 17 at the College of Advanced Technology, Gosta Green, under the tutorship of A. D. Hopkins, M.Sc., A.I.M., and a course of ten lectures on "Metallurgy of Deep Drawing and Pressing" to be held on successive Wednesday evenings at 6.30 p.m. started on January 18 under the course tutorship of J. C. Wright, B.Sc., Ph.D., A.I.M., A.M.Inst.F., A.C.T.(Birm.). The courses are arranged by the City of Birmingham Education Committee and are intended for metallurgists and engineers in industry engaged in research and development or materials control. Each meeting lasts for about two hours and includes a lecture, followed by a discussion.

APPOINTMENTS and STAFF CHANGES

Mr. J. Faulds has become the technical sales representative for **Kelvin Hughes** products in North and North-Eastern England, including the counties of Northumberland, Durham, Cumberland, Westmorland, North Riding of Yorkshire and Barrow-in-Furness. His address will be 110 Claremont Road, Whitley Bay, Northumberland.

* * *

Mr. S. H. Brooks has been appointed works manager (iron) at **Appleby-Frodingham Steel Co.**, a branch of The United Steel Companies. He succeeds Mr. N. D. Macdonald, who has become general works manager at **Workington Iron and Steel Company.** Mr. H. S. Ayres has been made assistant works manager (iron) of **Appleby-Frodingham.**

* * *

Thos. P. Headland Ltd., Melon Road, London, S.E.15, have appointed Mr. Frank Smith, A.M.I.Mech.E., as general sales manager. Mr. Smith will be responsible for all aspects of the company's selling activities.

* * *

Mr. E. V. Beatson of Joseph Lucas Ltd. has been appointed by the council of the **British Welding Research Association** to serve on the Association's research board. His principal fields of interest are resistance welding and brazing, his work on the latter being particularly well known through the book "Industrial Brazing" of which he was one of the joint authors.

* * *

The council of **The Institute of Physics and The Physical Society** of 47 Belgrave Square, London, S.W.1, have appointed Dr. D. Shoenberg of the Royal Society Mond Laboratory, Cambridge, as the Guthrie lecturer for 1961, and Dr. H. H. Hopkins of the Imperial College of Science and Technology to deliver the Thomas Young Oration in 1961.

The **Electrical Research Association** have appointed Mr. L. Gosland, B.Sc. (Eng.), M.I.E.E., as deputy director in addition to his position of research manager, and Mr. C. G. Garton, M.I.E.E., F.Inst.P., and Mr. E. W. Golding, O.B.E., M.Sc.Tech., M.I.E.E., M.Am.I.E.E., as assistant directors. Dr. R. H. Golde, D.Sc., M.I.E.E., has been appointed head of the Surges and Transformer Department and Mr. M. Waters, B.Sc., M.I.E.E., deputy head of that Department.

* * *

Mr. J. H. Hartrop has been appointed publicity manager of **Alfred Herbert Ltd.**, P.O. Box No. 30, Edgewick Works, Coventry, in succession to the late Mr. R. Buckley. He has been with the company for 27 years, and for the past 12 years, has held the position of assistant publicity manager.

OBITUARY

Watson: It is with regret that we announce the death of Mr. E. F. Watson, at the age of 51, as a result of a road accident. Mr. Watson was a director of Efco Furnaces Ltd., Queens Road, Weybridge, Surrey. He joined the company in 1933, after serving an apprenticeship with John M. Henderson and Co. Ltd., Aberdeen, and for many years he held the position of sales manager. He was appointed a director in 1955.

BORAX AND BORIC ACID PRICES

As a result of successful resistance by Borax Consolidated Ltd. of Borax House, Carlisle Place, London, S.W.1, the increase in ocean freight charges effective from January 1, has been temporarily reduced from that originally proposed and consequently, Borax Consolidated announce that they will limit the increase in prices to 10s. per ton from February 1. The reduction in the increase in freight charges is only applicable until April 1 when a further revision of prices may be inevitable.

CHALLENGE TO VITREOUS-ENAMEL INDUSTRY

A PLEA for the vitreous-enamel industry to unite in a powerful campaign to fight competition from other materials was made by Mr. S. W. Vickery, chairman of the Vitreous Enamel Development Council, at the annual meeting in London recently. He pointed out that at the moment the vitreous-enamel industry in Great Britain was facing a challenge in the development of competitive materials and while vitreous enamelled products were still vastly superior to all other materials for a great number of purposes, this challenge would require all the up-to-date methods of publicity to match those being used by competitors, in order to retain the industry's markets. Individual efforts in this campaign may, at worst, be wasted and the only chance of success lay in uniting as an industry to face the threat; in this respect, the V.E.D.C., formed in 1956, was doing a useful job and its publicity and promotional campaign, added Mr. Vickery, deserved the support of the industry as a whole in order that it could be intensified. Plans for 1961, to be made known shortly, include the sponsoring of a new vitreous-enamel symbol.

NEW MIDLANDS FACTORY FOR ALUMINIUM COMPANY

LACK of space for expansion and the necessity to improve methods of production for the wide range of products manufactured by them, has resulted in the decision of the London Aluminium Company to transfer three factories from Westwood Road, Witton, Tame Road, Witton and Oldbury to a vast 20-acre site at Wombourn, Staffs., where a £500,000 factory has been erected. The move commenced on November 28 and production started from the new factory on January 1, only six weeks after the start of the removal operation; it is expected that the new factory will be in full production by the end of March and it is predicted that by the end of the year, output will have increased considerably.

CHANGE OF ADDRESS

THE London office of Corrosion Ltd., Warsash Road, Warsash, Southampton, manufacturers of special coatings and treatments for metals, has been closed and all technical and service matters are now concentrated at Warsash.

Forthcoming Events . . .

February 6

Society of Instrument Technology (South Yorkshire Section). "Some Aspects of Instrumentation in Steelworks," by Dr. R. H. Baulk, Ph.D., M.Sc., M.Inst.P., A.M.I. Mech.E., at the University, St. Georges Square, Sheffield 1. 7.0 p.m.

February 7

Institute of Metals (South Wales Section). "Inspection of the High Strength Aluminium Alloys," by W. Smitham, B.Sc., F.I.M., in the Metallurgy Department, University College, Singleton Park, Swansea. 7.0 p.m.

Institution of Production Engineers (Midlands Region). "Automatic Equipment in the Metal Finishing Industry," by S. H. Grindod, at Courtaulds Lecture Theatre, Lockhurst Lane, Coventry. 7.30 p.m.

February 8

Institute of Sheet Metal Engineering (Midland Branch). "The Development and Building of Power Presses," by E. Hamilton at the Birmingham Chamber of Commerce, Harborne Road, Birmingham. 6.45 p.m.

Institute of Metals (Manchester Metallurgical Society). "Residual Stress and Stress Relieving," by L. E. Benson, D.Sc., F.I.M., at the Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

Institute of Sheet Metal Industries (North-West Branch). Forum. "Press Tools for Small Batch Production," in the Engineer's Club, 17 Albert Square, Manchester. 7.0 p.m.

February 9

Institute of Metals (Liverpool Metallurgical Society). "The Origin and Solution of Some Industrial Corrosion Problems," by E. C. Campbell, in the Department of Metallurgy, University of Liverpool. 7.0 p.m.

February 14

Institution of Production Engineers (Midland Region). "Shear on Press Tools," by J. A. Saunt, A.R.Ae.S., A.M.I.Prod.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham. 7.0 p.m.

February 15

Institution of Production Engineers (South Eastern Region). "New Welding Techniques," by G. Cubitt-Smith, A.M.Prod.E., G.I.Mech.E., at the Hoffman Manufacturing Centre. The Hoffman Manufacturing Co. Ltd., Chelmsford. 7.30 p.m.

North Wales Metallurgy Society. "The Yield Point in Mild Steel," W. S. Owen, Ph.D., Professor of Metallurgy, Liverpool University, in the Lecture Theatre, Flintshire Technical College, Connahs Quay, near Chester. 7.0 p.m.

Institution of Production Engineers (Midland Region). "Spark Erosion and its Applications," by B. J. Carver, B.Sc.(Eng.), A.M.I.Mech.E., at the G.K.N. Research Laboratory, Birmingham New Road, Lanesfield, Wolverhampton. 7.0 p.m.

February 16

Institute of Metals (North-East Metallurgical Society). "Plastics versus Metals," by P. T. Moore, B.Sc., Ph.D., D.I.C., A.R.S.M., A.I.M., and H. Hughes, B.Sc., in the Cleveland Scientific and Technical Institution, Corporation Road, Middlesborough. 7.30 p.m.

Institute of Metals (Birmingham Local Section). "The Growth and Prospects of the Aluminium Industry," by G. W. Lacey, C.B.E., B.Sc., F.R.I.C., at the College of Technology, Gosta Green, Birmingham. 6.30 p.m.

February 22

Society of Instrument Technology (Tee-Side Section). "New Steel-making Processes and their Control Problems," by Dr. P. A. Young, M.A., Ph.D. (Cantab.), at the Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough. 7.30 p.m.

Institute of Sheet Metal Industries (Wolverhampton Branch). Works visit to Joseph Sankey and Sons Ltd., Bilston.

Society of Instrument Technology (South Wales Branch). "The Manufacture, Properties and General Uses of Metal Bellows," by R. W. Houghton, in the Newport and Monmouthshire College of Advanced Technology, Cardiff. 6.45 p.m.

February 23

Institute of Metals (Metal Physics Committee). "The Theory of the Alloys of Copper," by Professor W. Hume-Rothery, O.B.E., F.R.S., of Oxford University, at the Royal Institution, Albemarle Street, London, W.1, on Thursday 23, 1961. 6.30 p.m.

March 2

Institute of Metals (Birmingham Local Section). "Rating Sheet Metal Formability by Press Performance," by D. H. Lloyd, F.R.I.C., F.I.M., at the College of Technology, Gosta Green, Birmingham. 6.30 p.m.

LOWER PRICES FOR TRICHLORETHYLENE AND PERCHLORETHYLENE

THE General Chemical Division of Imperial Chemical Industries have reduced the price of two important industrial solvents—trichlorethylene and perchlorethylene—as from January 1, 1961, the price of the former being reduced by £1 per ton and that of perchlorethylene by £5 per ton; the products are known in the dry-cleaning industry as "Triklone" and "Perklone" respectively. These reductions have been made possible by greater output following increased demand. When similar price reductions were announced a year ago, I.C.I. disclosed plans for a £1 million extension to the solvents plant operated by the General Chemical Division at Runcorn, Cheshire; this project is now well advanced and production is expected to start next summer.

RECORD OUTPUT OF STEEL

THE 1960 production figures of The United Steel Companies reveal record outputs of coke, rionstone, pig iron and steel, and for the first time in their history, the annual steel output has exceeded three million ingot tons, while pig iron production was over two million tons, also for the first time. Production at the Appleby-Frodingham Steel Co. reached 1,374,427 tons of ingot steel, Steel Peech and Tozer produced 1,158,147 tons, Samuel Fox and Co. Ltd. topped the 400,000 ton mark for the first time, and the Workington Iron and Steel Co's. steel output also reached a new high level at over 300,000 tons. Pig-iron production at the Appleby-Frodingham Steel Co. reached a record of 1,493,740 tons and at Workington exceeded 500,000 tons for the first time. Coke production at Appleby-Frodingham was increased by over 125,000 tons during the calendar year and the company's ore mining branch set a new record in ironstone production by beating the 1959 figure by 470,000 tons.

NEW PLANT and EQUIPMENT

A monthly review of new machines, equipment, processes, etc., of interest to the producer and user of sheet metal

PVC Finishing Coating Material

THREE grades of PVC finishing coating material which can be applied by spray-brushing, stoving and air drying and will adhere to all metals, wood, brick, concrete, and asbestos, has been produced by the Plasinter Co. Ltd. of Wednesbury, Staffs. PVC Spray-Stoving System, ref. MS/HC has been developed to meet the demands for finishes superior to normal stove-enamelling with similar coating thicknesses and is suitable for an almost unlimited range of ferrous and non-ferrous metal surfaces ; it can be applied to large and small articles to any desired film thickness from 0.0025 in. to 0.003 in. and upwards. The coating gives a tough flexible film with a hard, glossy, smooth surface and a vitreous-like finish and a warm feel ; it is suitable for indoor and outdoor use and has a high resistance to ageing and embrittlement. It can be applied over existing paintwork and is unaffected by corrosion, resistant to alkalis, alcohol, grease, oils, fats, and a good range of acids. It is a non-conductor of electricity, non-inflammable after processing, has high abrasion resistance, reduces handling noise, can be immersed in boiling water, retains its bright finish with normal cleaning and static electricity has been reduced to a minimum. It is available in a wide range of colours.

PVC Spray-Brush Air Drying System, ref. MS/AD, has been developed for surfaces that cannot be stoved and is suitable for ferrous and non-ferrous materials as well as wood, brick and asbestos. It has the same protective and other properties as the stoving system, including thickness of coating ; the finish, however, is an eggshell gloss. Its field of application is wider than the spray-stoving system MS/HC since it can be used on the inside and outside of buildings, ships hulls, etc.

The PVC Air Drying System, ref. MM/AD is a tough coating having all the qualities of the MS/HC and AD systems and a high resistance to acids and chemicals. It is particularly useful where atmospheric corrosion resistance is of major importance such as bakeries, breweries, dairies, distillers, gasworks, plating shops, etc. The finish has a slight orange peel appearance and is tough, yet resilient with excellent adhesion to most surfaces. The material has a high viscosity heavy bodied solution of plastic so formulated as to enable the application of a continuous coating in thicknesses of 0.005 in. to 0.015 in. or more, free from laps, joints or butts by continuous spraying and without formation of runs. As the efficiency of this kind of coating increases with film thickness, the ultimate thickness will be determined by the degree of protection required.

Strip Oiler

AS automation is applied increasingly to power press tools, so the need arises for thorough cleaning and lubrication of the strip before feeding into these machines. Clark's Press Equipment Ltd., of West Drayton, Middlesex, has recently introduced an oiler for strip. The mechanism comprises a box, which contains freely rotating felt rollers, and individual needle valves control the amount of lubricant fed to the cores of the rollers. Rubber squeegees, mounted at the point of entry, clean the material as it passes into the box.

By feeding of the lubricant to the centre of the roller, distribution as well as the amount of oil supplied is controlled, and there is less likelihood of excess lubricant dropping on to the floor or fouling the tools. The side of the lubricator can be opened, so that loading the material is a simple operation. The equipment has also been used for other purposes, such as the application of degreasers or thinners, prior to follow-on operations on the strip. Attachment to the press bed or to an automatic feed unit is claimed to be an easy matter.

Surface Finish Measurement

A PORTABLE surface measuring instrument has been manufactured by Payne Products International Ltd., Buckingham Avenue, Slough, Bucks. The instrument is an improvement on the previous model which was fitted with a meter showing centre line average readings and a graduated scale and selector knob used for the determination of maximum scratch depth from the mean centre line—the new version of the instrument provides a meter reading which by push-button selection indicates one of the following values ; Ra (centre line average), Rp (maximum height of profile from mean centre line), Rmax (maximum depth of scratches, peak to valley).

The instrument covers the range 0.300 microinches with three available "cut-off" lengths (waviness limited) as follows—0.003 in., 0.010 in. and 0.030 in. Various types of tracer heads are available for measuring flat surfaces, spherical surfaces, bores, tooth flanks, ball races, etc. The standard instrument is fitted with a stylus head of 4 mm. stroke length and a special model is obtainable providing three alternative stroke lengths between 1-2 mm. A pen recorder is also obtainable for providing permanent records of surfaces.

Toolroom Lathe

THE Series 75 H.S. lathe, Fig. 1, has been designed and manufactured by Woodhouse and Mitchell, Wakefield Road, Brighouse as a high precision machine, easy to operate and capable of maintaining its initial accuracy over many years. The bed is a strong box-section nickel-iron casting, diagonally braced to provide a rigid foundation for absorbing vibration. The carriage is guided on a large asymmetrical front "V" with a flat rear bearing. Additional "V" and flat guides are provided for the tailstock; these guides are left short so that, while the bed is of the normal straight pattern, increased swing is provided for a short distance in front of the spindle, giving some features of a gap bed machine and retaining rigidity of the straight bed. The drive to the input shaft of the headstock is taken from the main 2-speed motor by means of a toothed belt and a combination of electro-magnetic multi-disc clutches and constant mesh gears give, in conjunction with the 2-speed motor, two complete ranges of twelve different speeds each. The high-speed range has twelve speeds transmitted to the spindle over a toothed belt drive and a further range of low speeds is obtained by constant mesh back gearing; the result of this arrangement is a total of twenty-one different speeds in geometric progression with an overall range of 100-1, giving speeds from 30 r.p.m. to a maximum of 3,000 r.p.m. The speeds are pre-selected by rotary switch and the change effected by push-button without stopping the machine; further control buttons provide for stopping and braking and inching.

Standard Unit Construction Spray Booths

T. C. Spray Finishing Systems (Bede) Ltd., of 5, St. James's Place, London, S.W.1, have designed a standard unit system whereby a booth of any height, width or breadth is put together to fit in with the paint shop layout. The design is simple, quick, and cheap to instal and covers a wide range in size and purpose. The principal types of booth built on the standard unit principle are dry back booths, wet back spray booths and hot airless spray low-velocity booths.

Electronic Reading Automation

THE Solartron Electronic Group Ltd. of Farnborough, Hants., have designed a unit known as the Electronic Reading Automaton, which reads printed characters at very high speed and emits coded signals corresponding to the characters, which may be fed directly into a computor, be used to drive a card punch, or to punch paper or to write on magnetic tape. The reading speed is over 300 characters per second from either continuous rolls of paper or separate documents. The tally roll is the most compact form for recording transactions and lends itself to the use of standard recording equipment such as cash registers, adding machines and ledger machines. The size of separate documents that can be read is 6 in. by 3 in. to foolscap.

Portable Measuring Instrument

The East Lancashire Chemical Co. Ltd. of Fairfield, Manchester, have developed the Elcotector Mark II which is a battery-operated portable instrument designed to take measurements anywhere in the field or factory; its primary use is for all types of coating measurements on components and is capable of measuring the thicknesses of most metallic and non-metallic foils both in the static and moving state. It can therefore be used in a production run to give continuous readings of thickness, hardness or other changes as material is produced. Other duties include surface detection, the comparison of hardness of steel components and the variation between different types of alloys.

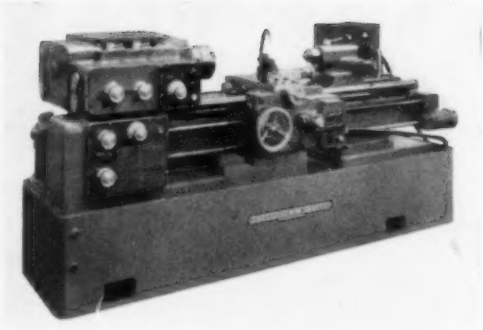


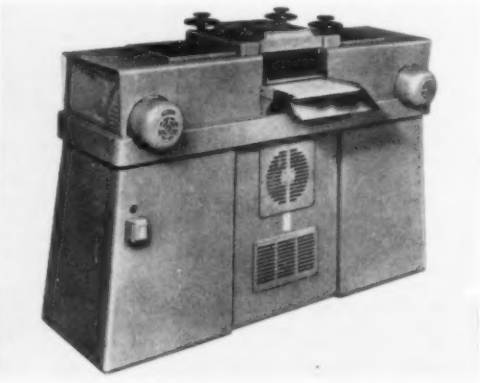
Fig. 1.—Toolroom lathe

Precision Flattening Machine

FIG. 2 shows the Schubert WM2 precision flattening machine for which the sole agents in this country are Vaughan Associates Ltd., 4 Queen Street, Curzon Street, London, W.1. Flattening is achieved by rollers and the pressure is adjustable to lie in the narrow range between the elastic limit and the yield point. The normal flattening accuracy obtainable with two passes of the machine is 0.0008 in. Working parts are housed within the frame in a floating mounting resulting in exceptionally quiet running. The motors drive distributor boxes through reduction gears and power is transmitted to the roller frame by shafts with universal joints; the flattening rollers are lapped and are hardened and profile-ground; the high-speed gears are mounted on ball bearings and the slow-speed gears and flattening rollers on plain bearings. Regulation is by four handwheels and accurate setting is ensured by dial indicators; once the setting has been determined for any workpiece it can be readily repeated, and in a production run all the operator is required to do is to feed the machine with workpieces which should be more than 1 in. in length, less than 13¾ in. in breadth and in the thickness range of $\frac{1}{32}$ in. to $\frac{1}{4}$ in. Output, depending on the size of the workpiece, is 200 to 1,500 components an hour and power consumption 3.5 kW. The material may be steel, light or heavy metal and may be in a soft condition, case hardened or nitrided.

(*Continued in page* 156)

Fig. 2.—Flattening machine



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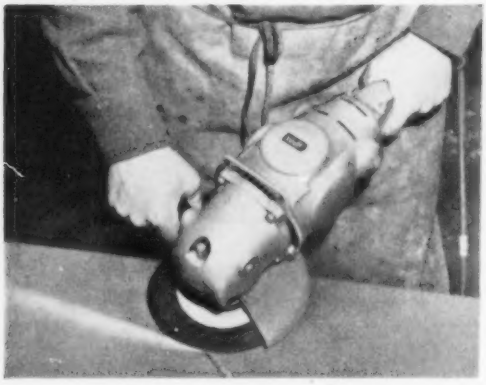
Double-insulated Angle Grinder

FIG. 3 shows the double-insulated high-speed angle grinder produced by Wolf Electric Tools Ltd., Pioneer Works, Hanger Lane, London, W.5, which is shrouded in a polyester resin with glass-fibre insulating material acting as a second barrier to the electricity, thus giving double insulation to full International C.E.E. standards and ensuring 100 per cent. safety against all electrical hazards of wiring systems and damp conditions.

The changing of discs is made simple by the inclusion of a spindle locking stud and the disc guard can be moved quickly to any required position around the discs. The motor operates at a low temperature and air is directed by special ducts over field and armature thus eliminating the possibility of metallic dust and build up.

The grinder is supplied in two sizes using 7 in. and 9 in. discs of $\frac{1}{16}$ in. to $\frac{1}{4}$ in. thickness operating on full load at 6,250 and 4,800 r.p.m. The universal motors are suitable for operation on 100/110, 110/130, 150/160, 200/220, and 220/250 volts, d.c. and single-phase a.c. 25/60 cycles.

Fig. 3.—Double-insulated angle grinder



Research and Industrial Polarograph

THE Tinsley Polarograph Mark 200, manufactured by Evershed and Vignoles Ltd. is an advanced instrument designed for both research and industrial requirements and suitable for applications covering investigations into electro-chemistry, stability constants of reducible compounds and characterization of certain complex organic materials; it is capable of trace determination of materials in solution to better than 0.02 p.p.m. The d.c. circuit employed permits operation from any type of electrode system, *i.e.*, D.M.E. vibrating and rotating solid electrodes, or pool electrodes, etc. The electrode may be positive or negative with respect to the reference electrode. The design embodies a galvanometer transistor d.c. amplifier which uses two parallel feed back circuits to adjust sensitivity in one feed back loop and speed of response in the other.

The potentiometer recorder itself has an effective chart width of 200 mm. allied to a response time of 1 second and embodies its own integral amplifier. Two chart speeds are provided and the overall sensitivity of the polarograph covers from 0.02-100 microamps for full scale deflection. A particularly interesting feature is the provision of a peak reading unit which eliminates capacity current noise from the normal D.M.E. and thus permits the chemist to obtain virtually undamped polarograms at all sensitivities without loss of resolution on both direct and derivative polarograms. Conventional damped polarograms may also be recorded (derivative type damping is used) and little or no zero shift will occur either with direct or derivative polarography. The potentiometer covers a voltage span from −0.5-3 and reverse with five scanning speeds for increased resolution.

The polarograph is housed in a metal case, finished to very high standards and makes use throughout of transistorized circuitry and printed circuits arranged in plug-in units to facilitate servicing and maintenance. The potentiometric recorder may also be used as a recording microammeter over its working range, without modification as suitable switching is provided.

Dial Calipers for Internal, External and Thickness Measurement

FIG. 4 shows one of a range of dial calipers produced by Carobronze Ltd., School Road, Belmont Road, London, W.4, for measuring the thickness of sheet metal, wall-thickness of tubes and castings, profiles, grooves, rounds, threads, and other internal and external thickness measurements. Rapid and accurate measurements may be taken by holding the gauge in one hand, leaving the other free to hold the test specimen. The gauge consists of a measuring mechanism and two protruding shanks, the lower shank being fixed and the other pivoted inside the gauge case. Contact points at the extremities of the shanks make close contact with the test specimen and the deflection of the pivoted shank is transmitted to the pointer. Contact arms are interchangeable and can be supplied in various lengths in steps of $\frac{1}{4}$ in. to cover measurements from 2 in. to 12 in. so that a series of different measurements can be taken with one instrument.

Fig. 4.—Dial calipers

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A NEW double-sided adhesive tape, "Twinstik," has been introduced by Industrial Adhesives Division of Evode Ltd., Stafford. The tape consists of a thin tissue which is impregnated with a special pressure-sensitive adhesive protected by a treated paper. It is available in a variety of widths up to 12 in. and can be applied to most surfaces to provide a strong and durable bond.

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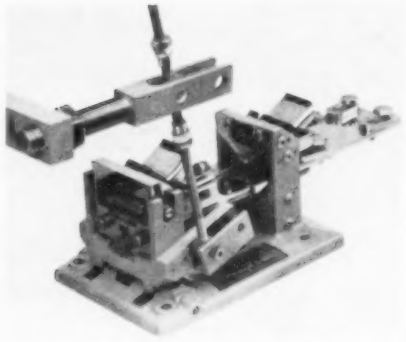

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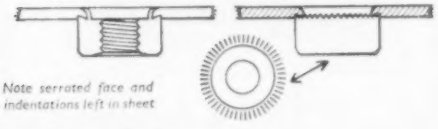

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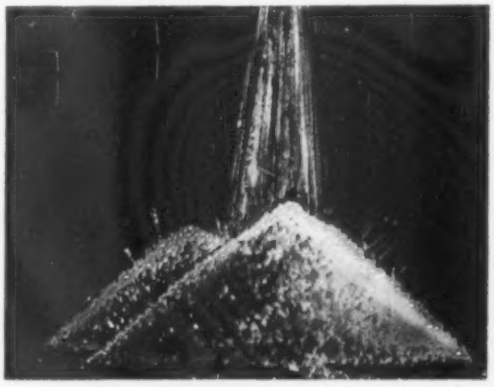

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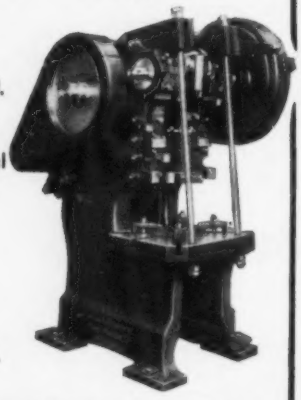

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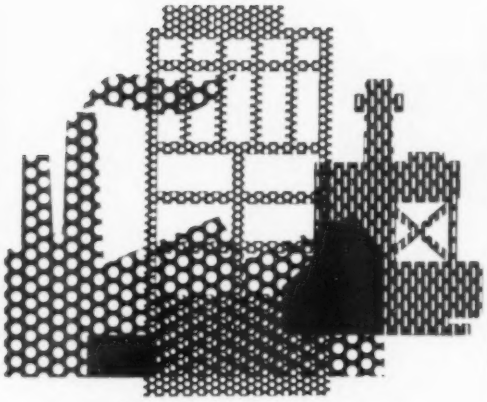

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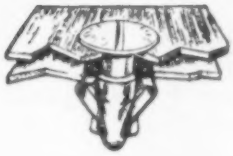

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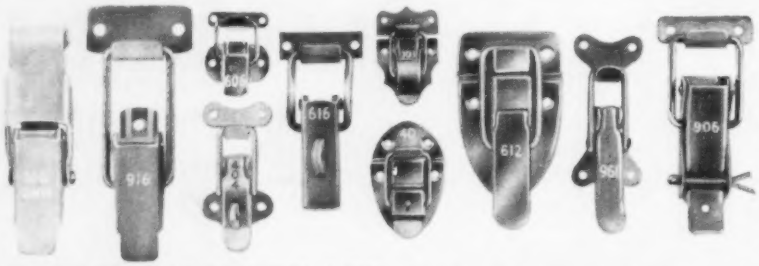

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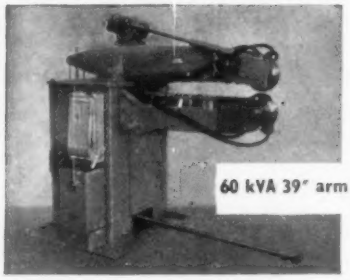

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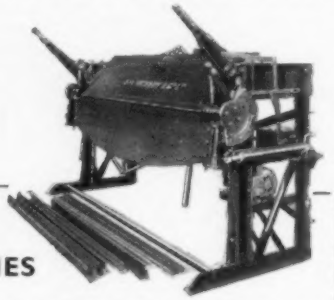

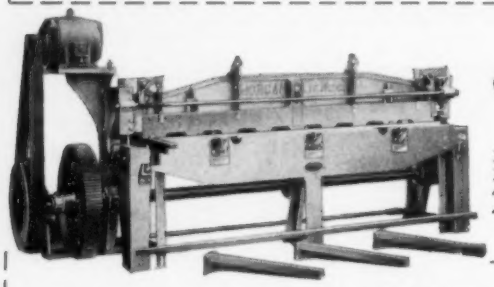

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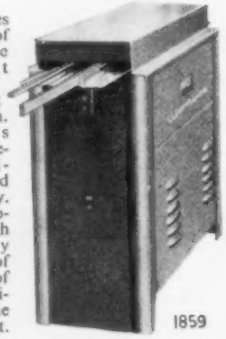

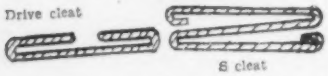

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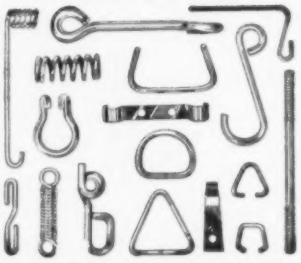

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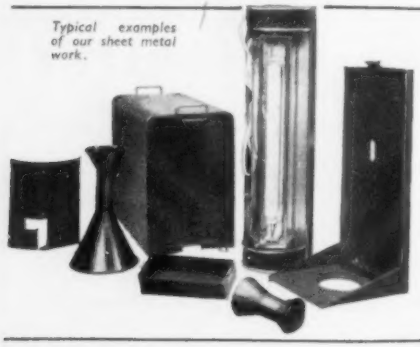

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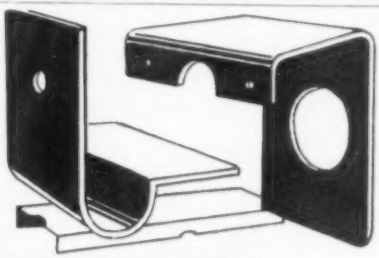

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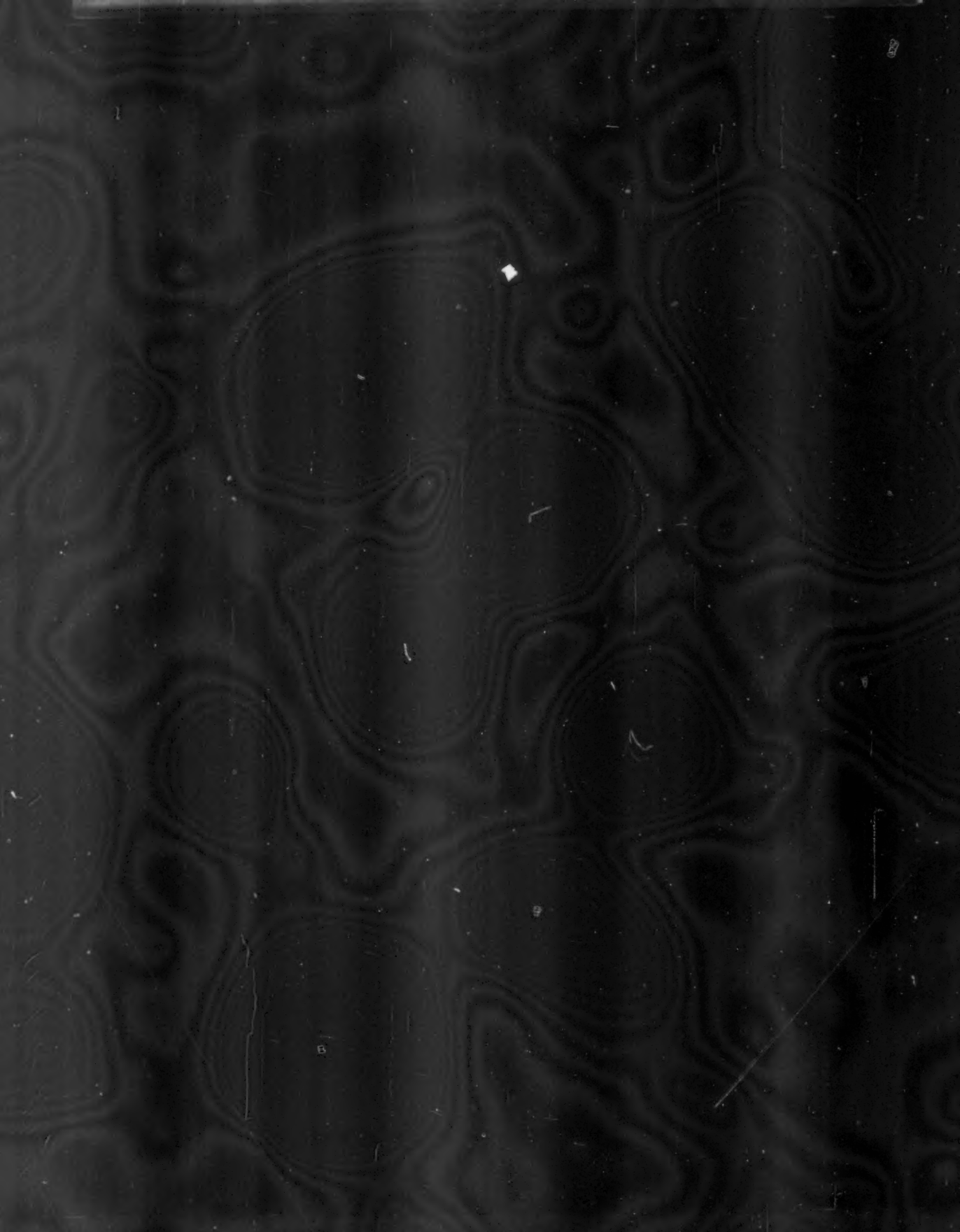
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